User Manual

PAC-T100 (Transformer Protection and Control Unit)

P&C Technologies Co., Ltd.

Safety Caution

It is contents to keep away user's safety and damage of property.
Use rightly after read manual attentively certainly.
Manual will be kept in place that a person who use product can see well.

Warning : In case of missed instructions, user can die or wound severe wound.

Caution : In case of missed instructions, user injures or property damage can occur.

REVISIONS

REV	Date	Description/Reason
1	July 10, 2009	1st English translation

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1 Overview

PAC-T100 is multifunction relay that have all protection, control and monitoring function. This relay is equipped instantaneous/percent differential, phase/ground (neutral)/negative sequence overcurrent to maximum three by winding, overexcitation, protection element of single phase overvoltage/undervoltage and is applicable to motor/generator winding protection as well as two/three winding transformer.
PAC-T100 has various measure and monitoring function such as quantity of electricity measure, self-diagnosis, and trip circuit supervision(TCS).
PAC-T100 has setting groups for four protection, and change and apply setting group according to system driving condition change and enables optimum protection.
This relay can be various and designs economically trip logic, inter-lock sequence and lock-out function without external addition logic or connection by programmable logic(Easy-Logic).
Event and waveform recording function of PAC-T100 offer driving history of necessary data and device to fault analysis.
PAC-T100 has event and waveform recording data that is stored even if control power is lost. Stored recording can analyze in PC after upload using front communication port in integration PC program (PACManager^{TM}).
PAC-T100 has 8 basis LEDs and 8 user setting LEDs, and offers convenient menu-tree through graphic LCD, and relay and circuit breaker can be controlled by keypad.
There is one RS-232 port that front of PAC-T100 can do in communication with PC program (PACManager^{TM}), and are two RS-232 ports that rear of PAC-F100 can do connection with remote monitoring system.
This relay provides ModBus, DNP3.0 and IEC 60870-5-103 protocol for communication with remote monitoring system.

1.1 Characteristics

- Digital transformer protective relay that use two processors
- Use possibility for two-windings or three-winding transformer protection
- Four protection element setting groups
- Eleven protection elements : HOCR, PHS DIFF, OCR, OCGR, NSOCR, GND DIFF, OVR, UVR, CBF, V/Hz, COLD LD, INRUSH
- Various TC curve : IEC standard, ANSI standard, KEPCO induction type, P&C curve
- Control of CB open/close on local and remote mode
- Quantity of electricity measuring function : Three-winding three-phase current, Single phase voltage, Three-winding sequence current, Differential current by a phase(Fundamental wave, Second harmonic wave, Fifth harmonic wave), Restrain current, Compensation current, Magnification by winding, Reference winding, Frequency
- 1024 event recording and maximum eight fault waveform recording (32 samples/cycles)
- Engineering tool : Setting change, Event inquiry, Fault waveform analysis
- Graphic LCD (240 128, 16line 30character) : Single line diagram, tree structure menu, 16 LEDs, 11 Keypad button
- Communication port : Front interface RS232 port 1 (ModBus Protocol : Setting change, Event/Fault waveform transmission, measuring monitor), Rear interface RS485 port 2 (SCADA communication, DNP3.0/ModBus/IEC60870- 5-103 protocol)
- Self-diagnosis function : DC power supply, Memory, CPU, Setting range, DSP, A/D converter, Analog input circuit, inside logic element and digital input/output circuit
- Trip circuit (TCS) monitoring function
- Eight user setting LEDs
- Panel design easiness in sequence logic structure through EasyLogic Editor
- Test function : Output relay and front display department
- Software upgrade easiness by flash memory use
- Flexible control source (option : AC 110 ~ 240 V, DC 19 ~ 130 V)
- Access Security by password for settings and CB control

1.2 Application

- Two-windings or three-winding transformer protection
- Current differential protection of generator and motor winding

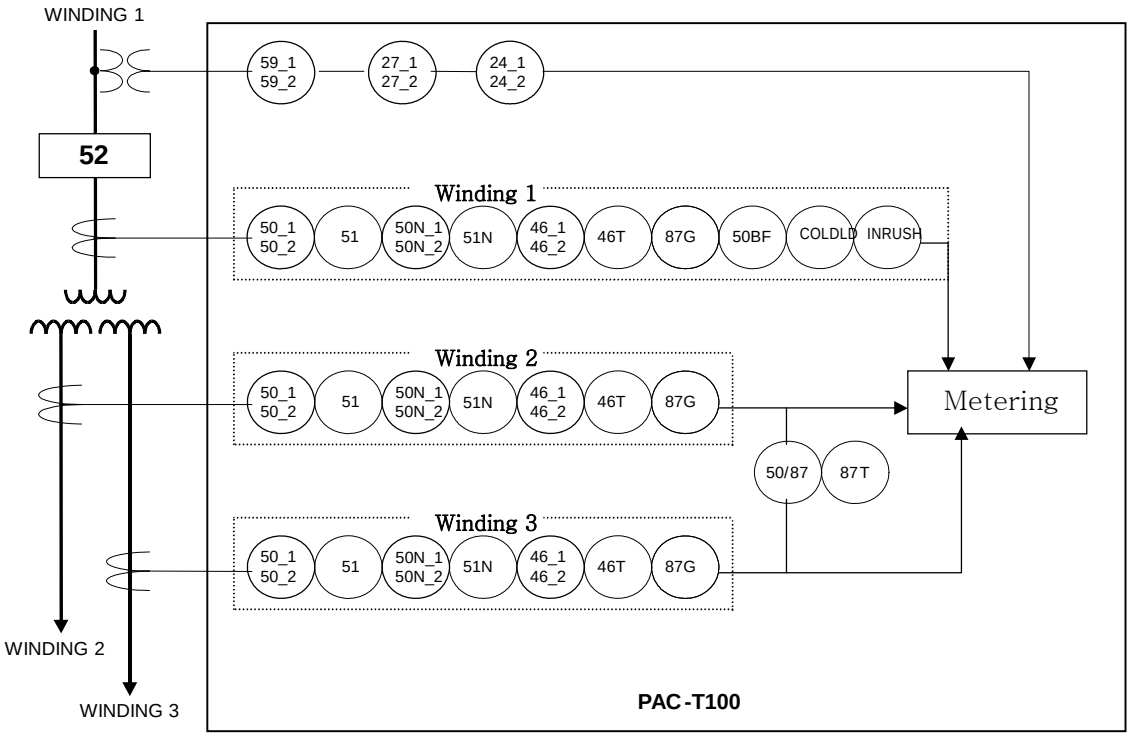

Figure 1-1 Function Single Line Diagram

Table 1-1 Device / Function

Device	Function
50/87	Instantaneous Differential Protection
87T	Percent Differential Protection
50_1, 50_2	Instantaneous / Definite Time Phase Overcurrent Protection
51	Inverse Phase Overcurrent Protection
50N_1, 50N_2	Instantaneous / Definite Time Ground(Neutral) Overcurrent Protection
51N	Inverse Ground(Neutral) Overcurrent Protection
46_1, 46_2	Instantaneous / Definite Time Negative Sequence Overcurrent Protection
46T	Inverse Negative Sequence Overcurrent Protection
87G	Restricted Ground Percent Differential Protection
59_1, 59_2	Overvoltage Protection
27_1, 27_2	Undervoltage Protection
24_1, 24_2	Overexcitation(V/Hz) Protection
50BF	Circuit Breaker Failure Protection
COLDLD	Cold Load Pickup
INRUSH	Inrush Detection

1.3 General Specification

1.3.1 Rated Control Power

Input	AC 110~220 V±20%(50/60 Hz), DC 80~300V, DC 19~130V * Normal operation duration in short-term power interruption is 100ms.
Power consumption	Below 30VA (Actually 15W)

1.3.2 Voltage

Rated Voltage	AC 50~240.0V(50/60Hz)
Input Range	1~450V
Overload Capability	Continuous(~450V)
Power Consumption	Below 0.5VA / Phase

1.3.3 Current

Rated Current	AC 5/1A (50/60Hz)
Input Range	0.1 ~ 250A(In : 5A), 0.02 ~ 50A(In : 1A)
Overload Capability	100×Inom for 1s, 20×Inom for 4s, 15A Continuous
Power Consumption	Below 0.5VA / Phase

1.3.4 Binary Output

Trip Contact (6 Points(6A), Configurable)	
Closed Circuit Capacity	16A / Continuous / AC 250V 30A / 0.3sec / DC 125V / Resistive load
Opened Circuit Capacity	5A / 0.1 (PF) / AC 250V 5A / 0.1 (PF) / AC 250V
Signal Contact (10 Points(8A, 2C), Configurable)	
Closed Circuit Capacity	5A / Continuous / AC 250V 5A / 0.3sec / DC 125V / Resistive
Opened Circuit Capacity	1A / 0.1 (PF) / AC 250V 1A / 25ms (L/R Time Constants) / DC 125V

1.3.5 Binary Input

Number	16, Configurable
Input Range	Maximum DC 250V
On/Off Threshold Voltage	DC 19~130V : Von ≥19V, Voff ≤14V DC 80~300V : Von≥80V, Voff ≤60V
Recognition Time	Less than 10ms

1.3.6 Communication Interface

Front Panel RS-232 (for PACManager™)
19200bps(fixed), 8bit/No parity/1 stop
ModBus Protocol
Rear Panel 2 Galvanic Isolated (for SCADA Communication)
COM2 is ModBus exclusive use
300 ~ 38400bps, 8bit/No parity/1 stop
Modbus/DNP3.0/IEC60870-5-103 Protocol

1.3.7 Case

Structure Draw-out type
Quality of the material Fe
Weight 6.5kg
Terminal U(spade)/Ring lug
Inside diameter : 5mm, Maximum outside diameter : 12mm

1.4 Test

1.4.1 Insulation Tests

Insulation Resistance
Standard IEC60255-5, ANSI/IEEE 37.90.0
Detail Contents 500 V DC
Circuit – Case 10 MΩ
Circuit – Circuit 5 MΩ
Contact – Contact 5 MΩ

Insulation Voltage Withstand Test
Standard IEC60255-5, ANSI/IEEE 37.90.0
Detail Contents For 1 minute (50/60 Hz)
Circuit – Case 4 kV
Circuit – Circuit 4 kV
Contact – Contact 2 kV

Impulse Voltage Withstand Test
Standard IEC60255-5, ANSI/IEEE 37.90.0
Detail Contents Waveform : 1.2×50μs
Permission Counter : 3th each Positive / Negative Polarity
Circuit – Case 5 kV
Transformer – Transformer 5 kV
Transformer – Control Circuit 5 kV
Control Circuit – Control Circuit 3 kV
Contact – Contact 3 kV

1.4.2 Noise Test

1MHz burst disturbance

Standard IEC60255-22-1, ANSI/IEEE C37.90.1
Detail Contents Oscillation Frequency : 1 MHz
Voltage Rise Time : 75 ns
Repetition Frequency : 400 Hz
Output Impedance : 200 Ω
Permission Method : Asynchronous
Polarity : Positive, Negative
Control Power Circuit : Common Mode 2.5 kV
Differential Mode 1.0 kV
Transformer Circuit : Common Mode 2.5 kV
Differential Mode 1.0 kV
Contact Circuit : Common Mode 2.5 kV
Differential Mode 1.0 kV

Fast transients / burst

Standard IEC60255-22-4 class Ⅳ, ANSI/IEEE C37.90.1
Detail Contents Voltage Rise Time : 5 ns
50% Peak Voltage Hold Time : 50 ns
Repetition Frequency : 2.5 kHz
Burst Hold Time : 15 ms
Burst Period : 300 ms
Permission Method : Asynchronous, Common- Mode
Polarity : Positive, Negative
Permission Time : 1 min
Downtime : 1 min
Control Power Circuit : 4kV
Transformer Circuit : 4kV
Contact Input / Output Circuit : 4kV
Earth Circuit : 4kV

Electrostatic Discharge

Standard IEC60255-22-2 class Ⅱ
Detail Contents Voltage Polarity : Positive, Negative
Permission Counter : 10
Permission Interval : 1 sec
Permission Region : Case
Air discharge: 8 kV
Contact discharge: 6 kV

Surge Immunity

Standard IEC60255-22-5 class Ⅳ
Detail Contents Voltage Waveform : 1.2×50 μs
Current Waveform : 8×20 μs
Output Impedance : 2 Ω
Permission Method : Asynchronous
Polarity : Positive, Negative
Permission Counter : 3
Permission Time Interval : 30 sec
Control Power Circuit : Common Mode 4.0 kV
Differential Mode 2.0 kV
Transformer Circuit : Common Mode 4.0 kV
Differential Mode 2.0 kV
Contact Circuit : Common Mode 4.0 kV
Differential Mode 2.0 kV

Radiated Susceptibility

Standard IEC60255-22-3 class III, ANSI/IEEE C37.90.2
Detail Contents Electric Field Intensity : 10 V/m
Permission Frequency : 80MHz~1GHz
Frequency Modulation : 1kHz Sine Wave 80% AM
Permission Direction : Front, Rear
Antenna Direction : Verticality, Horizontality
Dwell time: 1sec

Line Conducted HF

Standard IEC 61000-4-6 class III
Detail Contents Permission Frequency : 150kHz ~ 80MHz
Electric Field Intensity : 10 V
80% AM, 1kHz

1.4.3 Mechanical Test

Vibration

Standard IEC60255-21-1 class Ⅱ
Detail Contents Vibration Frequency : 16.7Hz
Amplitude of Vibration : 0.4mm
Vibration Direction : Front, Rear / Left, Right / Up, Down
Test Time : 600sec (10min)

Shock

Standard IEC60255-21-2 class II
Detail Contents Impulse : 30g (g : Acceleration of Gravity)
Permission Method : Front, Rear / Left, Right / Up, Down

1.4.4 Temperature and Humidity Test

Standard IEC 60068-2-1/2
Operating Temperature -25 ~ 70°C
Storage Temperature -30~75°C
Humidity RH 30~ 95%

1.5 Use Environment

Altitude	Less than 1000m
The others	Status of do not exist abnormal vibration, shock, slope and magnetic field Status of do not exist explosiveness dust, inflammable dust, inflammable/ corrosiveness dust and salt

1.6 Protection / Detection Elements

1.6.1 Current Differential Protection(50/87, 87T)

Transformer Setting

Type Y_Y, Y_D, …, D_D_D
Phase Compensation Internal(software), External
Phase difference between winding 0, 30, …, 330º lag

Winding Setting

Rated VA 0.01~600.00 MVA, 0.01 step
Rated Voltage 0.01~600.00kV, 0.01 step
CT Ratio 5~10000, 5 step
Ground Yes, No

Instantaneous Differential(50/87) Setting

Pickup Current 10~150A, 1 step
Operating Delay 0.00~60.00sec, 0.01 step

Percent Differential (87T) Setting

Pickup Current 0.20~2.50A, 0,01 step
Operating Delay 0.00~60.00sec, 0.01 step
Slope1 5~100 %, 1 step
Slope2 20~200 %, 1 step
Knee Point 5.0~100.0A, 0.1 step
Harmonic Restraint Mode None, 2^{nd} Harm, 5^{th} Harm, 2^{nd} or 5^{th} Harm
2^{nd} Harmonic Level(I2d/I1d) 5.0~40.0 %, 0.1 step
5^{th} Harmonic Level(I5d/I1d) 5.0~40.0 %, 0.1 step

1.6.2 Phase / Ground(Neutral) Overcurrent Protection(50/51, 50N/51N)

Pickup Current	0.50~100.00A, 0.01 step
Definite Time	0.00~60.00sec, 0.01 step
Time Multiplier(TM)	0.01~10.00, 0.01 step
TC Curve	**IEC**
	Normal Inverse(IEC_NI)
	Very Inverse(IEC_VI)
	Extremely Inverse(IEC_EI)
	Long Inverse(IEC_LI)
	ANSI/IEEE
	Inverse(ANSI_I)
	Short Inverse(ANSI_SI)
	Long Inverse(ANSI_LI)
	Moderately Inverse(ANSI_MI)
	Very Inverse(ANSI_VI)
	Extremely Inverse(ANSI_EI)
	Definite Inverse(ANSI_DI)
	KEPCO
	Normal Inverse(KNI)
	Very Inverse(KVI)
	Definite Normal Inverse(KDNI)

1.6.3 Negative Sequence Overcurrent Protection(46, 46T)

Pickup Current(I2)	0.50~ 100.00A, 0.01 step
Definite Time	0.00~60.00sec, 0.01 step
Time Multiplier(TM)	0.01~10.00, 0.01 step
TC Curve	Is same a Phase / Ground Overcurrent Protection

1.6.4 Restricted Ground Differential Protection(87G)

Pickup Current	0.20~2.50A, 0,01 step
Slope(Igd/Imax)	5~100%, 1 step
Operating Delay	0.00~60.00sec, 0.01 step

1.6.5 Overvoltage(59) / Undervoltage(27) Protection

Pickup Voltage	5~170V, 1 step
Definite Time	0.00~60.00sec, 0.01 step
Time Multiplier(TM)	0.01~10.00, 0.01 step
TC Curve	Appendix C. Inverse Characteristic Reference

1.6.6 Overexitation(V/Hz) Protection(24)

Minimum Voltage	5~50V, 1 step
Pickup(V/Hz)	1.00~4.00 V/Hz, 0.01 step
Operating Delay	0.00~180.00sec, 0.01 step

1.6.7 Circuit Breaker Failure Protection(50BF)

Trip Relay / Binary Input	T1~T6, DI1~DI16
Pickup Current(CB Closed)	0.20~ 2.50A, 0.01 step
Operating Delay(Trip Timer)	0.00~60.00sec, 0.01 step

1.6.8 Cold Load Pickup(COLDLD)

Current Detection Level 0.10~ 5.00A, 0.01 step Operating / Reset Delay 0~1000sec, 1 step

1.6.9 Inrush Detection(Inrush)

Minimum Current(I1f) 0.10~2.50A, 0.01 step Pickup(I2f/I1f) 10~100%, 1 step Operating Delay 0.00~60.00sec, 0.01 step

1.6.10 Protection Elements Accuracy

Pickup ± 3% of Setting Value Operating Time ±3% or ±40msec of Setting Value Dropout Level 96~98% of Pickup Value Dropout Time Less than 40msec Angle Accuracy ±3º

1.7 Additional Function

1.7.1 Measurement

Current Three-winding 3Phase current RMS / Angle, 0.05~250 A ±0.5%(0.5~45A), ±1.0%(>45A) Voltage Single phase voltage RMS / Angle, 1~450V,±0.5% Frequency Single phase voltage standard, 40~70 Hz (0.002Hz) Sequence Current Three-winding Positive, Negative, Zero Sequence RMS / Angle Differential Current Fundamental Wave / 2nd Harm / 5th Harm Differential Current Restraint Current Fundamental Wave Restraint Current Compensation Current Three-winding 3Phase Compensation Current RMS / Angle, 0.5~250 A Magnification by winding Three-winding Current Magnitude Compensation Factor Reference Winding Phase Compensation Reference Winding Display

1.7.2 Recording

Event Recording

Maximum recording number 1024
Resolution 1msec
Event Item Protection Status(Current / Voltage inclusion),
Contact Input / Output Status,
Setting Change, Circuit Breaker Control,
Control Power On/Off, Recording Data Clear,
Circuit Breaker Output Number Change etc.
Features When produce protection element event quantity of electricity(Three-winding Current, Voltage, Differential Current, Restraint Current, Magnification by winding) together recording
Even if control power is lost, data is kept

Waveform Recording

Maximum recording number Maximum eight according to setting
Sample number per cycle 32 samples/cycle
Record Type(Block × Cycle) 2×320, 4×160, 8×80
Trigger Position 0 ~ 99% (1% step)
Trigger Condition Setting by Logic operand
Sample Data Current, Voltage, Protection Status(Pickup, Operation),
Contact Input / Output Status
Features COMTRADE(IEEE C37.111) File Format
Even if control power is lost, data is kept

1.7.3 Sequence Logic(EasyLogic)

Operand Circuit Breaker Open/Close Control, Protection Operation Status,
Self-diagnosis Status, Monitoring Operation Status, Contact Input Status,
Logic Operation Status
Operator AND (2~8 inputs)
, OR (2~8 inputs)
, NAND(2~8 inputs)
, NOR(2~8 inputs)
, NOT
, LATCH (S,R)
, Timer (On, Off, Pulse)
Features Up to 48 operators can be used
Sequence logic is composed using Operand/Operator

1.7.4 Control

Circuit Breaker

Number 2 CB
Interlocking Through EasyLogic, freely composition possibility
Local Control Control because use KeyPad for control
Malfunction prevention by password input
Remote Control Control through rear RS-485 communication port or contact input

Setting Group

Number 4 Setting Group
Local Control Through KeyPad, change in Setting/System/Power System
Remote Control Change through rear RS-485 communication port

2 OPERATIONAL DESCRIPTION

2.1 Front Panel

Front panel of PAC-T100 is consisted of graphic LCD (240×128, 16line×30character), 16 LEDs and 11 keypad buttons and RS-232C communication port.

This relay becomes to prevent malfunction by password input when operate setting value change or control keypad. Protection function is achieved in interval that operate driving information through LCD, and marks update in case of event of priority order occurs.

If connect PACManager™ on front RS232C port, setting value change, work of event/fault waveform/MIN/MAX recording transmission is available conveniently to notebook.

Figure 2-1 Front Panel

Table 2-1 LED/LCD Function

LED/LCD		Function
(1) LCD		Setting Value, Measurement Value, Driving Screen display
(2) "RUN/TEST"		"GREEN", Lighting a LED when input control power , Flicker a LED when it is contact output/front display department test
(3) "ERROR"		"RED", Lighting a LED when occur system error , LED status reset through 'RESET' Key
(4) "PICKUP"		"YELLOW", Lighting a LED when is protection element pickup
(5) "TRIP"		"RED", Lighting a LED when is protection element operation , LED status reset through 'RESET' Key
(11) Control	"L/R" LED	"GREEN"(Local)/"RED"(Remote) Local/Remote control possibility status display
	"OPEN" LED	"GREEN" Lighting a LED when circuit breaker is open status
	"CLOSE"LED	"RED" Lighting a LED when circuit breaker is close status
(12) Programmable LED		"RED", eight, Through EasyLogic Editor, function set

Table 2-2 Key Function

KEY		Function
(7) Direction Key	∧	The first measurement item change Menu change, Setting value range change
	∨	
	>	Menu change, Menu item select
	<	Menu change, Escape(A high position menu move, Item cancel)
(8) RESET		"ERROR" LED and "TRIP" LED reset EasyLogic 'ANN_RESET' Operand' operation
(9) MENU		From early screen to Menu Tree screen move
(10) ENTER		Setting value input and Command Menu Yes/No Confirm
(11) Control	L/R	Local/Remote control position change
	SELECT	Circuit breaker choice to control
	OPEN	Choice circuit breaker open control
	CLOSE	Choice circuit breaker close control

(13) PACManager connection RS-232 communication port

LCD screen of PAC-T100 is separated into greatly early screen and menu composition screen. Early screen can see information of various measured data, system time information, event number, fault waveform number, setting group etc. to use ∧ ∨ direction key.

2.2 Early screen

Product model, communication status, six measure display, event and waveform recording save number, single diagram, a choice circuit breaker name, system time, setting group of present are registered to early screen.

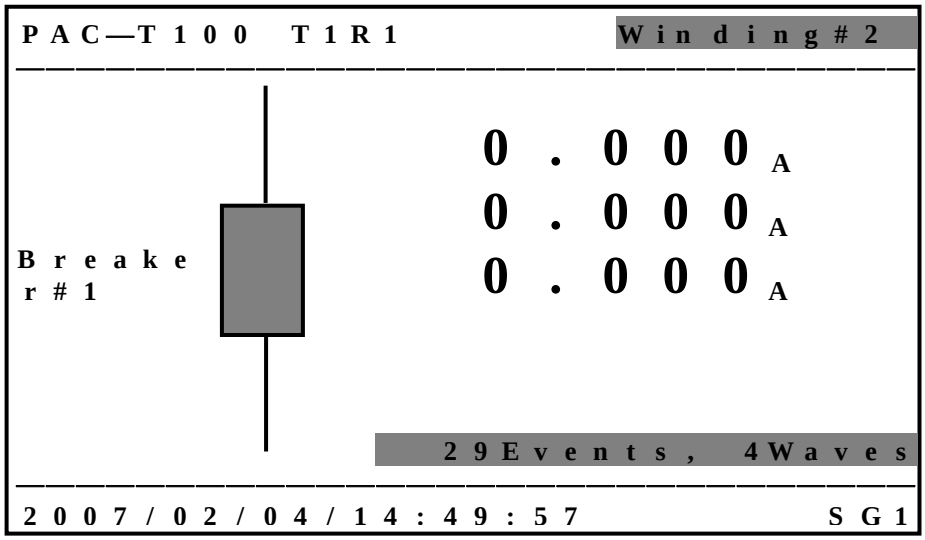

Figure 2-2 LCD Early screen

2.2.1 Measured data

Early measurement screen of PAC-T100 is consisted of total 6 and each item can confirm using up and down direction key. Composition contents of early measurement screen are same lower part.

Table 2-3 LCD Early measurement screen item

LCD display item	Description
WINDING#1	Winding#1 Primary Current(A, B, C, N Phase)
WINDING#2	Winding#2 Primary Current (A, B, C, N Phase)
WINDING#3	Winding#3 Primary Current (A, B, C, N Phase)
A PHASE	A-Phase Primary Current (1, 2, 3 Winding)
B PHASE	B-Phase Primary Current (1, 2, 3 Winding)
C PHASE	C-Phase Primary Current (1, 2, 3 Winding)

2.2.2 Circuit breaker status display and control

Control authority of circuit breaker and present state of circuit breaker are registered by LED though circuit breaker sets function of ***SETTING/SYSTEM/BREAKER/BREAKER#1*** by EANBLED and picture of circuit breaker is expressed on LCD screen. Circuit breaker is not expressed, and must set function of ***SETTING/SYSTEM/BREAKER/BREAKER#1*** by EANBLED in case of LED of circuit breaker controlling means have turned off on LCD screen.

Circuit breaker is not expressed even if BREAKER#1's function is set by DISABLED, and BREAKER#2's function was set by EANBLED. In case of circuit breaker was set normally, status is registered by open(□) or close(■) in LCD. BREAKER#1's function is set by EANBLED and circuit breaker was expressed on LCD screen, must set circuit breaker setting again after it is rapidly if the subroutine appears as absurd(☒ or ▬) and circuit breaker status LED(open, close) flickers.

In case of circuit breaker status is registered by Error(☒), 52a input and 52b input of circuit breaker were set by all None or when function of set digital input is set by DISABLED, set according to circumstance in case of it is None because it is and must set function of relevant digital input through EasyLogic Editor of PACManagerTM by EANBLED in case digital input is set by DISABLED. Must set normally after inspect catenate status of digital input and status of circuit breaker because mean that status of circuit breaker 52a digital input and 52b digital input has same cost in case of circuit breaker status is registered by trouble(■).

In case of control authority must become local and controls circuit breaker in remote through communication in case of control circuit breaker on the spot, control authority must become remote. Press L/R key in case of control authority setting differs and must change control authority. Circuit breaker control authority change is as following. L/R key -> Control Password input -> ENTER key -> L/R key. Circuit breaker control authority change is possible in local.

When make control authority of circuit breaker by local to control circuit breaker on the spot, I press SELECT key. I press ENTER key after input control password moving particularly each position using up(⋀), down(⋁), left(<), right(>) key in case of ask password. If press SELECT key after input right password, picture of circuit breaker blink.
If press SELECT key better two times in case of want control of the second circuit breaker, picture of the second circuit breaker blink.
Press OPEN or CLOSE key according to user's intention and controls circuit breaker. If do control command such as present state, in case of phrase which is already present state orders LCD to appear for the lower line and differs with present state the command phrase LCD for the lower line appear and contact output that control command is established acts. When control local CB, password must be input.

Can control in high position communication or SCADA through RS485 communication after make control authority of circuit breaker through circuit breaker control authority change method by Remote status in case of want circuit breaker control in Remote.

2.2.3 The other display

Time registered under LCD for line means now system time and "EVENTS", "WAVES" displays recorded event, fault data number. Setting group of protection element that "SG1" is applied present means GROUP#1.

"T1R1 (T2R2)" display of LCD first line marks transmission of RS485 communication and reception. "T1" means tx data of COM1 and "R1" means rx data of COM1 and "T2" means tx data of COM2 and "R2" means rx data of COM2.

2.2.4 Display switchover

Relay is switched over automatically by ***PROTECTION*** item of ***DISPLAY/STATUS*** menu if protection element operates in measurement screen. Relay return by early screen if automatic switchover condition is returned and key operation does not occur more than 3 minutes.

LCD returns by early screen as backlight turns off if do not handle key for 3 minutes.

2.2.5 LED Latched Status Clear

"TRIP" LED Clear

"TRIP" LED is lighted up in case of protection element more than one operates by representative LED of protection element action. "TRIP" LED Clear presses RESET key 2 times when all protection elements are reset. First, if show protection element that operate because is converted automatically by ***DISPLAY/STATUS/PROTECTION*** menu if presses RESET key and presses the second RESET key, status is initialized.

"ERROR" LED Clear

"ERROR" LED is lighted up in case of self-diagnosis element more than one operates by representative LED of self-diagnosis status display. "ERROR" LED Clear presses RESET key 2 times when all self-diagnosis elements are returned. First, if show self-diagnosis element that operate because is converted automatically by ***DISPLAY/STATUS/ SELF_DIAGNOSIS*** menu if presses RESET key and the second RESET key, status is initialized.

2.3 Menu structure display

Menu composition screen is separated into DISPLAY block that mark status, metering, record etc, and SETTING block that set or displays setting value of system and protection element and COMMAND block that can initialize record and set trip counter of circuit breaker and status of point of contact and test front panel.

Menu tree key handle

Relay is switched over in menu composition screen if press MENU key in early screen. Refer menu composition screen, can select menu wanting through up( ), down(), left( ), right( ) key.

Example 1) In case of move from early screen to event screen
MENU(DISPLAY) (STATUS) (METERING) (RECORD) (EVENT)

Example 2) In case of move from event screen to RTC setting screen
(RECORD) (DISPLAY) (SETTING) (SYSTEM) (PASSWORD)
(POWER SYSTEM) (RTC)

Relay is switched over to details menu if press right() key in least significant menu. It is meaning that details menu is extant more than two in case of title of the first line blinks in details menu. Press right() key if details menu to change setting after presses up(), down() key is published and select details menu. In the case of ***SETTING/PROTECT#*** item, protection group of present state blinks if press right() key, and come to low order menu if press right() key after choose protection group which wish to change setting pressing up(), down() key.

Details item of menu configuration item wants to refer menu composition screen.

Table 2-4 Menu composition screen

Early screen	DISPLAY	STATUS	CONTACT INPUT		Contact input status
			CONTACT OUTPUT		Contact output status
			LED		Programmable LED status
			LOGIC COMPONENT		EasyLogic Component status
			SELF_DIAGNOSIS		Self-diagnosis status
			PROTECTION		Protection operation status
		METERING	METERING		Power quantity metering
		RECORD	EVENT		Event occur data
			WAVEFORM		Fault waveform data
		SYS INFO			MPU and DSP version
	SETTING	SYSTEM	PASSWORD		Password setting
			POWER SYSTEM		Power system and wiring setting
			RTC		System time setting
			WAVEFORM RECORD		Waveform record setting
			BREAKER		Circuit breaker status and setting
			COMMUNICATION		COM1, 2 setting
			TCS		Trip Circuit Supervision setting
		EASY LOGIC	CONTACT INPUT		Contact input setting display
			CONTACT OUTPUT		Contact output setting display
			LED		Programmable LED setting display
			LOGIC COMPONENT		EasyLogic Component setting display
		PROTECT #1 ~ #4	HOC(50/87)		Instantaneous Differential setting
			PHS DIFF(87T)		Percent Differential setting
			WINDING #1~#3	OC(50/51)	Overcurrent setting
				OCG(50N/ 51N)	Ground overcurrent setting
				NSOC (46/46T)	Negative sequence overcurrent setting
				GND DIFF	Restricted Ground Percent Differential setting
			OV(59)		Overvoltage setting
			UV(27)		Undervoltage setting
			CBF(50BF)		Circuit breaker fail setting
			V/Hz(24_1)		Overexcitation(V/Hz) 1 setting
			V/Hz(24_2)		Overexcitation(V/Hz) 2 setting
			COLD LD		Cold Load Pickup setting
			INRUSH		Inrush detection setting
	COMMAND	CLEAR EVENT			Event data clear
		CLEAR WAVEFORM			Waveform data clear
		CONTACT OUT TEST			Contect output test
		PANEL TEST			Front panel LCD/LED tedt
		TRIP COUNTER SET			Circuit breaker trip counter setting
		LCD CONTRAST			LCD contrast setting

2.4 DISPLAY

This menu show digital input and contact output status, user appointment LED status, Logic Component status, self-diagnosis status, monitoring element and protection element operation status, firmware's version information in DISPLAY.

2.4.1 STATUS

This menu show operation status of digital input and contact output, user appointment LED operation status, EasyLogic component status, self-diagnosis status, operation availability of TCS and protection element in ***DISPLAY/STATUS***. Status information that do not appear on screen can confirm using up(), down() key. Protection element is registered element that function is set by ENABLED.

CONTACT INPUT

DISPLAY/STATUS/CONTACT INPUT can confirm present state of 16 digital inputs. Digital input that function is set by EANBLED is registered as 'OFF' in case of it is logic 0 as 'ON' in case of input is logic 1. Digital input that function is set by DISABLED is registered as 'OFF' regardless of input state.

CONTACT OUTPUT

DISPLAY/STATUS/CONTACT OUTPUT can confirm present output state of 16 contact output. Contact output that function is set by EANBLED is registered as 'ENERGIZED' in case of was displayed, and is registered as 'DEENERGIZED' in case of output was not made. Contact output that function is set by DISABLED is registered as 'DEENERGIZED'.

LED

DISPLAY/STATUS/LED can confirm output state of 8 user appointment LED. LED that function is set by EANBLED is registered as 'OFF' in case of 'ON', output was not made in case of output was made. LED output that function is set by DISABLED is registered as 'OFF'.

LOGIC COMPONENT

DISPLAY/STATUS/LOGIC COMPONENT can confirm present state of 48 logic component. Logic component that function is set by EANBLED is registered as 'OFF' in case of it is logic 0 as 'ON' in case of input is logic 1. Logic component that function is set by DISABLED is registered as 'OFF'.

SELF_DIAGNOSIS

DISPLAY/STATUS/SELF DIAGNOSIS can confirm self-diagnosis status. Relay is registered as 'OK' in case of it is particularly normally each item. Relay is registered as 'FAIL' in case of is absurd and SYSTEM ERROR LED is lighted up.
Self-diagnosis item is memory, setting range, AD converter, DC power, CPU exception, DSP, analog input circuit, Easylogic setting, contact input circuit, contact output circuit. There is trip circuit supervision (TCS) by monitoring function. If set TCS function by DISABLED, relay is always registered as 'OK'.

PROTECTION

Protection element set by DISABLED is not shown in ***DISPLAY/STATUS/PROTECTION***, and pickup of protection element and operation status set by EANBLED is confirmed only. Operation status is displayed by the phase when it is 3-phase protection element, relay is registered as 'A' if A-phase is operated. Relay is registered as 'OP' in case it is single-phase

protection element. When there is no used protection element, phrase 'NO PROTECTION ENABLED' is registered. Relay is switched over in ***DISPLAY/ STATUS / PROTECTION*** screen at pickup and operation occurrence of protection element in early measurement screen.

2.4.2 METERING

Various metering value are confirmed in ***DISPLAY/METERING***.
Standard of phase display is winding#1 A-phase current (W1_IA). Refer to below table(2.5) for details contents about metering display.

Table 2-5 Measurement display

LCD Title	Item	Description
WINDING#1 CURRENT	IA	Winding#1 A-Phase primary current magnitude, angle (Standard angle)
	IB	Winding#1 B-Phase primary current magnitude, angle
	IC	Winding#1 C-Phase primary current magnitude, angle
	IN	Winding#1 N-Phase primary current magnitude, angle
	VA	Single phase Primary voltage magnitude, angle
	FREQUENCY	Single phase frequency of voltage
	REF_WIND	Reference winding of CT Ratio compensation
	W1_MFAC	Winding#1 current compensation factor
	W2_MFAC	Winding#2 current compensation factor
	W3_MFAC	Winding#3 current compensation factor
WINDING#2 CURRENT	IA	Winding#2 A-Phase primary current magnitude, angle
	IB	Winding#2 B-Phase primary current magnitude, angle
	IC	Winding#2 C-Phase primary current magnitude, angle
	IN	Winding#2 N-Phase primary current magnitude, angle
WINDING#3 CURRENT	IA	Winding#3 A-Phase primary current magnitude, angle
	IB	Winding#3 B-Phase primary current magnitude, angle
	IC	Winding#3 C-Phase primary current magnitude, angle
	IN	Winding#3 N-Phase primary current magnitude, angle
COMPENSATED CURRENT	W1_C_IA	Winding#1 A-Phase secondary compensation current magnitude, angle
	W1_C_IB	Winding#1 A-Phase secondary compensation current magnitude, angle
	W1_C_IC	Winding#1 A-Phase secondary compensation current magnitude, angle
	W2_C_IA	Winding#2 A-Phase secondary compensation current magnitude, angle
	W2_C_IB	Winding#2 B-Phase secondary compensation current magnitude, angle
	W2_C_IC	Winding#2 C-Phase secondary compensation current magnitude, angle
	W3_C_IA	Winding#3 A-Phase secondary compensation current magnitude, angle
	W3_C_IB	Winding#3 B-Phase secondary compensation current magnitude, angle
	W3_C_IC	Winding#3 C-Phase secondary compensation current magnitude, angle
DIFFERENTIAL CURRENT	DIFF_IA	A-Phase fundamental wave secondary differential current magnitude

	DIFF_IB	B-Phase fundamental wave secondary differential current magnitude
	DIFF_IC	C-Phase fundamental wave secondary differential current magnitude
	DIFF2_IA	A-Phase 2 harmonics secondary differential current magnitude
	DIFF2_IB	B-Phase 2 harmonics secondary differential current magnitude
	DIFF2_IC	C-Phase 2 harmonics secondary differential current magnitude
	DIFF5_IA	A-Phase 5 harmonics secondary differential current magnitude
	DIFF5_IB	B-Phase 5 harmonics secondary differential current magnitude
	DIFF5_IC	C-Phase 5 harmonics secondary differential current magnitude
RESTRAINT CURRENT	R_IA	A-Phase fundamental wave secondary restraint current magnitude
	R_IB	B-Phase fundamental wave secondary restraint current magnitude
	R_IC	C-Phase fundamental wave secondary restraint current magnitude
PHASE A CURRENT	W1_IA	Winding#1 A-Phase primary current magnitude, angle (Standard angle)
	W2_IA	Winding#2 A-Phase primary current magnitude, angle
	W3_IA	Winding#3 A-Phase primary current magnitude, angle
	W1_C_IA	Winding#1 A-Phase secondary compensation current magnitude, angle
	W2_C_IA	Winding#2 A-Phase secondary compensation current magnitude, angle
	W3_C_IA	Winding#3 A-Phase secondary compensation current magnitude, angle
	DIFF_IA	A-Phase fundamental wave secondary differential current magnitude
	DIFF2_IA	A-Phase 2 harmonics secondary differential current magnitude
	DIFF5_IA	A-Phase 5 harmonics secondary differential current magnitude
	R_IA	A-Phase fundamental wave secondary restraint current magnitude
PHASE B CURRENT	W1_IB	Winding#1 B-Phase primary current magnitude, angle (Standard angle)
	W2_IB	Winding#2 B-Phase primary current magnitude, angle
	W3_IB	Winding#3 A-Phase primary current magnitude, angle
	W1_C_IB	Winding#1 B-Phase secondary compensation current magnitude, angle
	W2_C_IB	Winding#2 B-Phase secondary compensation current magnitude, angle
	W3_C_IB	Winding#3 B-Phase secondary compensation current magnitude, angle
	DIFF_IB	B-Phase fundamental wave secondary differential current magnitude

	DIFF2_IB	B-Phase 2 harmonics secondary differential current magnitude
	DIFF5_IB	B-Phase 5 harmonics secondary differential current magnitude
	R_IB	B-Phase fundamental wave secondary restraint current magnitude
PHASE C CURRENT	W1_IC	Winding#1 C-Phase primary current magnitude, angle (Standard angle)
	W2_IC	Winding#2 C-Phase primary current magnitude, angle
	W3_IC	Winding#3 C-Phase primary current magnitude, angle
	W1_C_IC	Winding#1 C-Phase secondary compensation current magnitude, angle
	W2_C_IC	Winding#2 C-Phase secondary compensation current magnitude, angle
	W3_C_IC	Winding#3 C-Phase secondary compensation current magnitude, angle
	DIFF_IC	C-Phase fundamental wave secondary differential current magnitude
	DIFF2_IC	C-Phase 2 harmonics secondary differential current magnitude
	DIFF5_IC	C-Phase 5 harmonics secondary differential current magnitude
	R_IC	C-Phase fundamental wave secondary restraint current magnitude
SEQUENCE CURRENT	W1_I0	Winding#1 zero sequence primary current magnitude, angle
	W1_I1	Winding#1 positive sequence primary current magnitude, angle
	W1_I2	Winding#1 negative sequence primary current magnitude, angle
	W2_I0	Winding#2 zero sequence primary current magnitude, angle
	W2_I1	Winding#2 positive sequence primary current magnitude y, angle
	W2_I2	Winding#2 negative sequence primary current magnitude, angle
	W3_I0	Winding#3 zero sequence primary current magnitude, angle
	W3_I1	Winding#3 positive sequence primary current magnitude, angle
	W3_I2	Winding#3 negative sequence primary current magnitude, angle

2.4.3 RECORD

Event occurrence contents and waveform save information are confirmed in ***DISPLAY /RECORD***.

DISPLAY/RECORD/EVENT show record of maximum 1024 stored in memory of PAC-T100. All fault records are recorded with information occurrence time by resolution of 1msec, and managed by FIFO mode. Fault record items have control power ON/OFF, protection element operation status, contact input/output status, circuit breaker control, setting value change, monitoring/self-diagnosis status, event data clear, waveform record clear and circuit

breaker counter change etc. Event is possible for setting EANBLED/DISABLED each function.
Event for operation status of protection element records fault informations (winding#1 ~ #3 current, voltage, differential current, restrain current and Magnification by winding). Event record is shown through LCD and confirmed in local or remote through PACManager™.

DISPLAY/RECORD/WAVEFORM shows total number of recorded fault waveform, trigger time and trigger data stored in memory. Trigger source and block element, simple explanation is included in fault contents. Relay does record possibility to block of maximum eight according to waveform recording setting. Resolution is 32 samples per cycle and maximum write time per block is 6.4 seconds (50Hz, 2 block standards). Waveform recording have Current/voltage, contact input/output status, sample data of protection element operation status and is confirmed in local or remote through PACManager™ to upload. Waveform recording is recorded to COMTRADE file. This file can do fault analysis, and use in fault reappearance through protection relay tester.

2.4.4 SYS INFO

DISPLAY/SYS INFO shows version information of MPU and DSP.

2.5 COMMAND

This menu has several command as follows, power energy delete, event delete, waveform record delete, thermal data clear, MIN/MAX data clear, contact output test, front panel test, circuit breaker counter setting and LCD contrast setting.

2.5.1 CLEAR EVENT

This menu clear event data stored to PAC-T100. If run “Clear Event”, all of the stored event data are initialized.

Event clear

(1) Press right(>) key after find CLEAR Event in COMMAND menu.
(2) Press ENTER key after input SET password using up(∧), down(∨) key moving by each position using left(<), right(>) key in case of ask password in last line of screen.
(3) After input right password, contents to erase if press right(>) key are published and phrase 'NO' blinks. This time, come out menu pressing left(<) key in case of does not want delete, or presses ENTER key in phrase 'NO'.
(4) Press ENTER key if phrase 'YES' is expressed after use up(∧), down(∨) key.
Relay is converted in COMMAND screen after phrase 'ALL CLEARED' is expressed for screen last line.

2.5.2 CLEAR WAVEFORM

This menu clear waveform data stored to PAC-T100. If run “Clear Waveform”, all of the stored waveform data are initialized.

Waveform clear

(1) Press right(>) key after find CLEAR Waveform in COMMAND menu.
(2) Press ENTER key after input SET password using up(∧), down(∨) key moving by each position using left(<), right(>) key in case of ask password in last line of screen.
(3) After input right password, contents to erase if press right(>) key are published and phrase 'NO' blinks. This time, come out menu pressing left(<) key in case of does not want

delete, or presses ENTER key in phrase 'NO'.
(4) Press ENTER key if phrase 'YES' is expressed after use up(), down() key.
Relay is converted in COMMAND screen after phrase 'ALL CLEARED' is expressed for screen last line.

2.5.3 CONTACT OUT TEST

It is menu to test 16 points of output contacts. If convert in test screen, done output contact turns into Enegized by all De-enegizeds. If test is preceded, LED "RUN/TEST" blinks.

Contact out test

(1) Press right() key after find CONTACT OUT TEST in COMMAND menu.
(2) Press right() key after output point of contact to test uses and selects up(), down() key.
(3) Press ENTER key after input SET password using up(), down() key moving by each position using left(), right() key in case of ask password in last line of screen.
(4) After input right password, contents to 'RESET MIN/MAX?' if press right() key are published and phrase 'NO' blinks. After input right password, phrase of contact output that is expressed by 'DEENERGIZED' if press right key blinks.
(5) Status of point of contact toggles by 'ENERGIZED' and 'DEENERGIZED' whenever press up(), down() key. And sound that RELAY sticks or drops sounds. LED "RUN/TEST" blinks during test.
(6) Relay escapes in test of contact output that select if press left() key.
Repeat (2)~(6) in case of want test of other contact output. When test again, password does not ask. Relay escapes in test display if press left() key in case of do not want test for contact output more.

2.5.4 PANEL TEST

It is menu to test 16 LEDs and LCD in front panel. If test front panel, all LEDs are turned during 1 second and 'PAC-T100' character is expressed to LCD. And, these tests are repeated 3 times.

Panel test

(1) Press right() key after find PANEL TEST in COMMAND menu.
(2) Press ENTER key after input SET password using up(), down() key moving by each position using left(), right() key in case of ask password in last line of screen.
(3) After input right password, test is executed if press right() key.
Relay is converted in COMMAND menu screen after test is executed 3 times.

2.5.5 TRIP COUNTER SET

It is menu to change trip counter of two circuit breakers. When change relay singleness, must set circuit breaker trip counter ago relay replace for circuit breaker supervision.

TRIP COUNTER SET change

(1) Press right() key after find TRIP COUNTER SET in COMMAND menu.
(2) Circuit breaker that want change in circuit breaker trip counter setting display presses up(), down() key and selects. Press right() key after select circuit breaker.
(3) Press ENTER key after input SET password using up(), down() key moving by each position using left(), right() key in case of ask password in last line of screen.
(4) After input right password, trip counter digit blinks if press right() key. Relay stores

automatically if press ENTER key after make into value to set pressing up(), down() key. Relay escapes in trip counter setting display if press left() key after setting ends.

2.5.6 LCD CONTRAST

It is menu to control LCD screen brightness. There is the possibility of difference for brightness of screen according to position or ambient temperature installed relay. User can control screen brightness according to environment of placed relay.

LCD CONTRAST setting

(1) Press right() key after find LCD CONTRAST in COMMAND menu.
(2) Press right() key in LCD CONTRAST change display.
(3) Press ENTER key after input SET password using up(), down() key moving by each position using left(), right() key in case of ask password in last line of screen.
(4) After input right password, LCD CONTRAST ratio blinks if press right() key.
(5) Press ENTER key after press up(), down() key and finds wanted screen brightness.
Because brightness ratio changes between 80.0 ~ 99.9%, when change from 99.9% to 80%, observe because can change as suddenly display is white. If is pressing up(), down() key continuously, LCD screen brightness changes continuously. Relay escapes LCD CONTRAST screen if press left() key after setting ends.

3 Function

3.1 General

SETTING menu is to display or change setting value that need in function achievement of relay. The present setting value can be confirmed by front key handling. But in case of change setting value Input password should be confirmed.

Setting by front panel

(1) Press right(>) key after select change item to use up(∧), down(∨) key in details menu to change setting value.
(2) Press ENTER key after input SET password using up(∧), down(∨) key moving by each position using left(<), right(>) key in case of ask password in last line of screen. (Password initial value is '0000')
(3) After input right password, setting value blinks if press right(>) key. In case of inputted wrong password, relay asks password again.
(4) Press ENTER key after select value that wish to set pressing up(∧), down(∨) key.
(5) If press left key before press ENTER key, relay returns by setting value ago.
(6) In case of return by early screen using left(<) key, relay asks setting save availability. This time, relay is stored by changed setting value if press up(∧), down(∨) key and press ENTER key after selects 'YES'.
(7) In case of selected 'NO', set value is canceled. In case of change several items at the same time, password does not require several times if do not escape ***SYSTEM*** or ***PROTECT*** block.

If use PACManager™, setting is possible conveniently.

3.1.1 SYSTEM

System setting item have password, power system, RTC, waveform recording, circuit breaker, communication, TCS.

3.1.2 PASSWORD

Password used in relay is ***SET PASS*** and ***CTRL PASS***. ***SET PASS*** is used when change setting value. ***CTRL PASS*** is used when control circuit breaker by keypad. Two passwords are four figures that are consisted of 0 ~ 9, and initial value at product shipping is all '0000'.

If forget it after change password, setting value is not changed or control by key handling.

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3.1.3 POWER SYSTEM

There is POWER SYSTEM for analog circuit composition setting, TRANSFORMER for transformer setting and WINDING#1 ~ #3 for analog circuit composition by each winding in ***SETTING/SYSTEM/POWER SYSTEM***. Setting group applied present according to SET GROUP's setting in POWER SYSTEM is decided.

Rated frequency

Rated frequency should sets equally with frequency of power system because it is important element that is used in metering of relay and protection arithmetic. When power system frequency differs with set frequency, measured data is shaken extremely or causes error in operaing characteristic of protection element. Rated frequency setting through keypad or PACManger™ possible. Should do control power of relay OFF-ON in case rated frequency

setting is changed.

PT Ratio

Relay is 1 voltage inputs. This voltage is source of overexcitation (V/Hz), overvoltage, undervoltage protection elements that use voltage. Should set PT secondary by the rated voltage inputted to relay considering wiring (line to line voltage or phase voltage) of PT primary in case use overexcitation (V/Hz) protection element. PT ratio setting can set using keypad or PACManager™.

Metering display voltage value = ***(PHS PT PRI/ PHS PT SEC)****input voltage (V)

Protection element setting group

Relay has 4 different groups about protection element. Setting group can set using ***SETTING/ SYSTEM/ POWER SYSTEM/ POWER/SYSTEM*** menu or PACManager™ or remote communication.

SETTING/ SYSTEM/ POWER SYSTEM/ POWER SYSTEM(삭제)

Setting item	Range(Step)	Unit	Description
1. FREQUENCY	60Hz, 50Hz		Rated frequency
2. PHS PT PRI	0.1 ~ 1000999.9 (0.1)	V	PT Primary
3. PHS PT SEC	50.0 ~ 250.0 (0.1)	V	PT Secondary
4. SET GROUP	GROUP#1 ~ GROUP#4		Protection group setting

3.1.4 Transformer

Transformer type

PAC-T100 supports type of 2 windings transformer (Y-Y, Y-△, △-Y, △-△) and three-winding transformer (Y-Y-Y, Y-Y-△, Y-△-Y, Y-△-△, △-Y-Y, △-Y-△, △-△-Y, △-△-△). For example, transformer that transformer primary winding is wye (Y) and secondary winding is delta (△) sets by Y-△.

Phase Compensation/ Ground current compensation when is outside grounding fault

PAC-T100 regardless of transformer winding basically CT Y-connection use and corrects phase difference by transformer winding as software in inside. In this case, ***TRANSFORMER/PHS COMP*** should sets by INTERNAL..
When install CT for phase compensation on outside, must set ***TRANSFORMER/PHS COMP*** by EXTERNAL. Divide √3 times current that grow into √3 again when PAC-T100 does not phase correction if set by EXTERNAL, and current quantity compensation by difference of CT ratio and CT wiring are delta and corrects current quantity difference by CT wiring.

In INTERNAL phase compensation setting, phase difference of transformer winding sets lag phase angle of secondary winding about primary winding through W1-W2 PHS and W1-W3 PHS. By example, must set W1-W2 PHS by 30˚ in case of secondary winding of Y-△ transformer is 30˚lag to primary winding.

Standard winding of phase compensation does via delta winding. Delta winding that transformer that have delta winding more than 1 is first in the third winding order in primary becomes standard winding of phase compensation. Primary winding of Y-Y or Y-Y-Y transformer that delta winding does not exist is standard winding. PAC-T100 removes ground current about transformer external grounding fault automatically by changing wye winding by delta connection via delta winding as software. Y-Y or Y-Y-Y wiring that consist of YES in GROUNDING setting of SETTING/SYSTEM/POWER SYSTEM/WINDING#1~#3 only in

occasion ground current compensation expression apply. Setting and phase compensation expression refer attachment A. phase compensation formula and attachment B. transformer type and compensation angle in transformer type.

Current quantity compensation

Current magnitude compensation does winding that CT rate of margin about rated current of each winding is the lessest by standard winding. That is, saturation margin of CT compensates current magnitude of modulo winding via the lessest winding.

Have NORM VOLT(V_{norm}[w]), RATED LOAD(P_{rated}[w]), PHS CT RATIO(CT_{ratio}) of ***SETTING/SYSTEM/POWER SYSTEM/WINDING#1~#3*** and relay calculates rated current(I_{margin}[w]) by winding. Relay calculates CT margin(I_{margin}[w]) using rated current by winding that run arithmetic. Choose winding that CT margin is less by standard winding(W_{ref}) and calculates magnitude compensation value of each winding about standard winding(W_{ref}). Magnitude compensation value is applied in differential current of high overcurrent element(50/87) and current ratio differential element(87T) and restraint current arithmetic.

$$I_{rated}[w] = \frac{P_{rated}[w]}{\sqrt{3} \bullet V_{norm}[w]} \quad , \quad \mathrm{w} = 1,2,3 \ ; \mathrm{winding}$$

$$I_{margin}[w] = \frac{CT_{ratio}[w]}{I_{rated}[w]}$$

$$M[w] = \frac{V_{rated}[w] \bullet CT_{ratio}[w]}{V_{rated}[w_{ref}] \bullet I_{rated}[w_{ref}]} \quad , \quad \mathrm{w}_{\mathrm{ref}} = reference_winding$$

Phase/Quantity Compensation example

Transformer	Setting	Unit
1. TYPE	D-Y	
2. PHS COMP	INTERNAL	
3. W1-W2 PHS	30	◦ lag
3. W1-W3 PHS	--	◦ lag
Winding#1		
1. NORM VOLT	154.00	kV
2. RATED LOAD	60.00	MVA
3. PHS CT RATIO	1200	: 5
4. GND CT RATIO	5	: 5
5. GROUNDING	NO	
Winding#2		
1. NORM VOLT	23.00	kV
2. RATED LOAD	60.00	MVA
3. PHS CT RATIO	2000	: 5
4. GND CT RATIO	5	: 5
5. GROUNDING	YES	

(1) Phase compensation

Reference winding : △ winding(winding#1)

Phase compensation value : Θw1 = 0-0 = 0, Θw2 = 0-(-30) = +330 °lag
Ground current remove (0. 0. reference)

Winding#1 phase compensation : $\dot{I}_A^* = \dot{I}_A, \dot{I}_B^* = \dot{I}_B, \dot{I}_C^* = \dot{I}_C$

Winding#2 phase compensation :
$$\dot{I}_A^* = 1/\sqrt{3}\dot{I}_A - 1/\sqrt{3}\dot{I}_B$$
$$\dot{I}_B^* = 1/\sqrt{3}\dot{I}_B - 1/\sqrt{3}\dot{I}_C$$
$$\dot{I}_C^* = 1/\sqrt{3}\dot{I}_C - 1/\sqrt{3}\dot{I}_A$$

(2) Rated current arithmetic,

$$I_{rated}[1] = \frac{60MVA}{\sqrt{3} \bullet 154kV} = 224.94A, \quad I_{rated}[2] = \frac{60MVA}{\sqrt{3} \bullet 23kV} = 1506.13A$$

(3) Rate of CT margin arithmetic,

$$I_{margin}[1] = \frac{240}{224.94} = 1.07 \quad , \quad I_{margin}[2] = \frac{400}{1506.13} = 0.27$$

Secondary winding that rate of margin is less becomes standard winding(W_{ref}).

(4) Current compensation value arithmetic,

$$M[1] = \frac{154 \bullet 240}{23 \bullet 400} = 4.017 , \quad M[2] = \frac{23 \bullet 400}{23 \bullet 400} = 1.000$$

(5) Current magnitude/phase compensation current($I^C_A[w]$, $I^C_B[w]$, $I^C_C[w]$)

$$\dot{I}_A^C[w] = \dot{I}_A^* \bullet M[w]$$
$$\dot{I}_B^C[w] = \dot{I}_B^* \bullet M[w]$$
$$\dot{I}_C^C[w] = \dot{I}_C^* \bullet M[w]$$

SETTING/ SYSTEM/ POWER SYSTEM/ TRANSFORMER

Setting item	Range(Step)	Unit	Description
1. TYPE	Y_Y, …, D_D_D		Transformer type
2. PHS COMP	INTERNAL, EXTERNAL		Phase compensation method INTERNAL : Software EXTERNAL: Compensation by outside CT wiring
3. W1-W2 PHS 4. W1-W3 PHS	0/30/60 … /270/300/330	◦ lag	Winding#2 for winding#1, winding#3 for winding#1 lag phase angle

SETTING/ SYSTEM/ POWER SYSTEM/ WINDING#1~#3

Setting item	Range(Step)	Unit	Description
1. NORM VOLT	0.01 ~ 600.00 (0.01)	kV	Winding rated voltage
2. RATED LOAD	0.01 ~ 600.00 (0.01)	MVA	Winding rated load
3. PHS CT RATIO	5 ~ 10000 (5)	: 5	Winding phase CT primary ratio
4. GND CT RATIO	5 ~ 10000 (5)	: 5	Winding ground CT primary ratio
5. GROUNDING	YES, NO		Winding grounding selection

Metering and EasyLogic Operand

LCD display Item	Description

REF_WIND	Current magnitude compensation reference winding(W_{ref})
W1_MFAC	Winding#1 current magnitude compensation factor(M[1])
W2_MFAC	Winding#2 current magnitude compensation factor(M[2])
W3_MFAC	Winding#3 current magnitude compensation factor(M[3])

3.2 Protection

Protection element setting of relay is attained through ***SETTING/PROTECT#x***.
Protection element is instantaneous/percent differential protection (50/87, 87T), phase/ground overcurrent protection by windings (50/51, 50N/51N), negative sequence overcurrent protection by windings (46, 46T), restricted ground fault protection by windings (87G), circuit breaker fail protection (50BF), cold load pickup, inrush detection.

FUNCTION, BLOCK, EVENT

There is setting item that select FUNCTION, BLOCK, EVENT to all protection elements commonly. This setting item can run protection function in particular condition if connect with EasyLogic. When FUNCTION is enabled and input of BLOCK setting is logic'1', function of protection element is suspended. Protection function does not act if FUNCTION is disabled and event is not recorded. If EVENT is disabled even if FUNCTION is enabled, event is not recorded.

3.2.1 Instantaneous/percent differential protection(50/87, 87T)

Current differential protection is consisted of percent differential protection (87T) that have instantaneous differential protection (50/87) that act by difference current magnitude regardless of magnitude of restraint current, and acts according to ratio property of restraint current and differential current magnitude.

Differential current/Restraint current calcurate

3.1.4 Relay calculates differential current (DIFF_IA, DIFF_IB, DIFF_IC) and restraint current (R_IA, R_IB, R_IC) by compensating current of each winding that phase compensation expression explaining in transformer, magnitude compensation by CT ratio difference, ground current compensation etc. are applied. Differential current by each phase is vector sum of each winding compensating current, and restraint current is 1/2 of scholar sum.

Differential current,

$$DIFF_IA = \dot{I}_A^C[1] + \dot{I}_A^C[2] + \dot{I}_A^C[3]$$
$$DIFF_IB = \dot{I}_B^C[1] + \dot{I}_B^C[2] + \dot{I}_B^C[3]$$
$$DIFF_IC = \dot{I}_C^C[1] + \dot{I}_C^C[2] + \dot{I}_C^C[3]$$

Restraint current,

$$R_IA = (|\dot{I}_A^C[1]| + |\dot{I}_A^C[2]| + |\dot{I}_A^C[3]|)/2$$
$$R_IB = (|\dot{I}_B^C[1]| + |\dot{I}_B^C[2]| + |\dot{I}_B^C[3]|)/2$$
$$R_IC = (|\dot{I}_C^C[1]| + |\dot{I}_C^C[2]| + |\dot{I}_C^C[3]|)/2$$

$\dot{I}_A^C[w], \dot{I}_B^C[w], \dot{I}_C^C[w]$: Winding compensation current

Instantaneous differential protection(50/87)

Instantaneous differential protection acts instantaneous if magnitude of differential current becomes more than setting value.
Differential current is magnitude of vector difference of calculated compensating current through compensation expression and not difference of current magnitude that pass to winding.

Percent differential protection(87T)

Current percent differential protection acts by instantaneous/definite time according to ratio setting of restraint current and differential current. Ratio property can do second-stage setting by low current area and high current area. Percent differential protection element has 2 harmonics / 5 harmonics constraint element to prevent malfunction by inrush or overexcitation of transformer. Also, when it is wye grounded system outside grounding fault, relay is equiping function that correct ground current that occur. Current percent differential protection element uses wye connection CT basically, but already can accommodate CT for placed phase compensation.

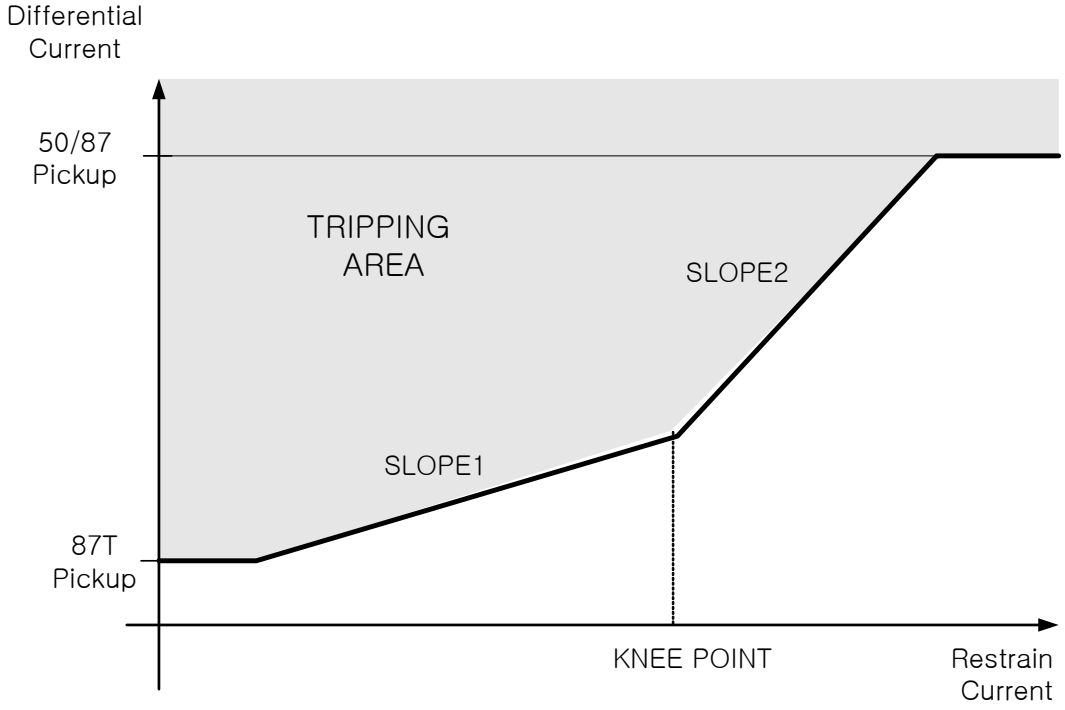


Figure 3-1 Current instantaneous/percent differential protection operating characteristic

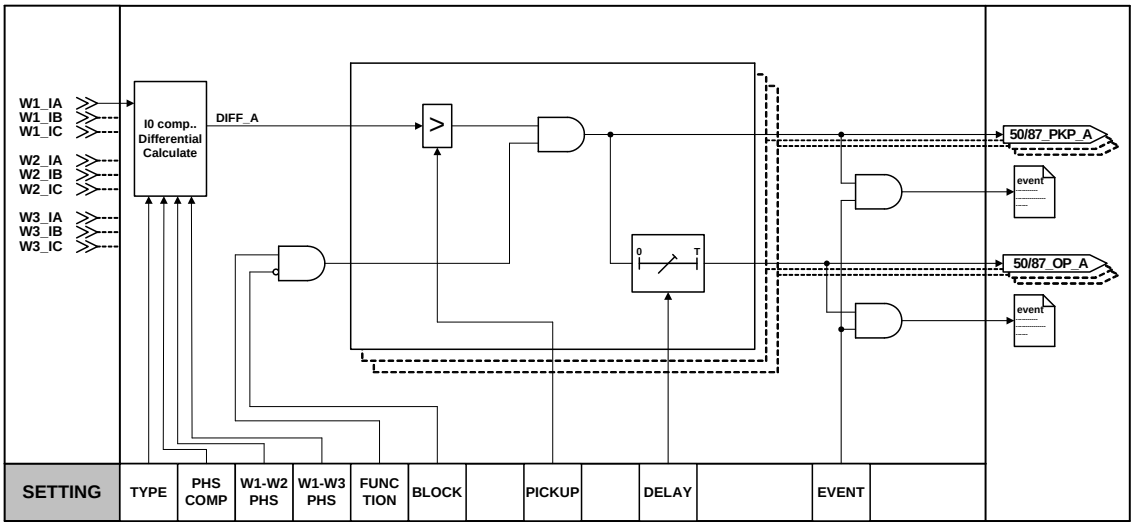


Figure 3-2 Current instantaneous differential protection operating characteristic

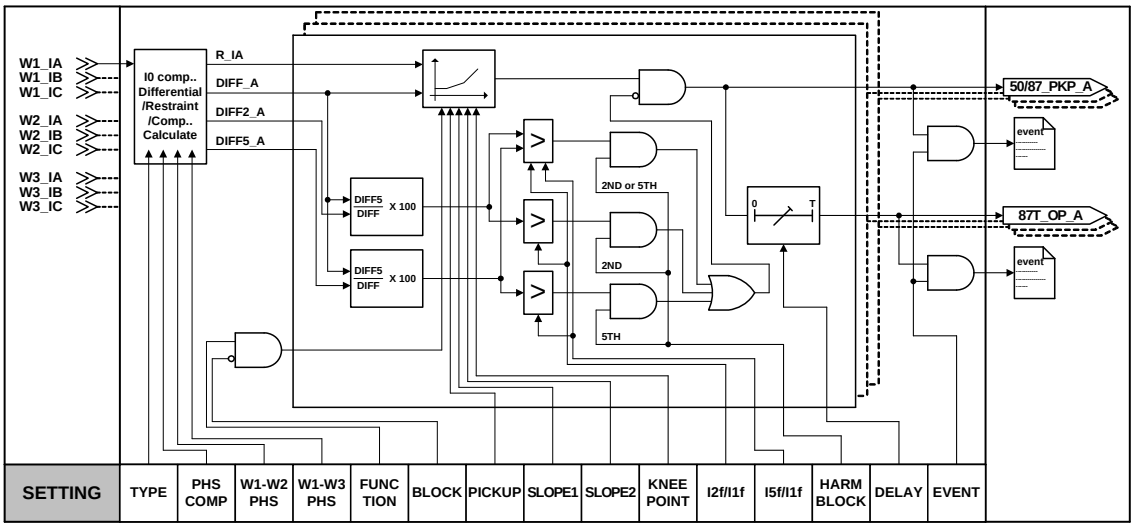


Figure 3-3 Current percent differential protection operating characteristic

SETTING/ PROTECT#1~#4/ HOC(50/87)

Setting Item	Step	Unit	Description
1. FUNCTION	ENABLED, DISABLED		Whether function use or not
2. PICKUP	10 ~ 150A (1)	A	Differential current Pickup
3. DELAY	0.00 ~ 60.00(0.01)	sec	Operating delay time
4. BLOCK	EasyLogic operand		Protection blocking condition
5. EVENT	ENABLED, DISABLED		Whether event record or not

SETTING/ PROTECT#1~#4/ PHS DIFF(87T)

Setting Item	Step	Unit	Description
1. FUNCTION	ENABLED, DISABLED		Whether function use or not
2. PICKUP	0.20 ~ 2.50(0.01)	A	Differential current Pickup
3. SLOPE1	5 ~ 100(1)	%	Low current area ratio setting
4. SLOPE2	20 ~ 200(1)	%	High current area ratio setting
5. KNEE POINT	5.0 ~ 100.0(0.1)	A	Border current of low current area and high current area
6. HARM BLOCK	NONE, 2ND, 5TH, 2ND+5TH		Harmonics restraint element selection NONE : Harmonics restraint element not use 2ND:2 harmonics use 5TH:5 harmonics use 2ND+5TH:2 harmonics + 5 harmonics use
7. I2f/I1f	5.0 ~ 40.0	%	(2 harmonics differential current / fundamental wave differential current)*100
8. I5f/I1f	5.0 ~ 40.0	%	(5 harmonics differential current / fundamental wave differential current)*100
9. DELAY	0.00 ~ 60.00	sec	Operating delay time
10. BLOCK	EasyLogic operand		Protection blocking condition
11. EVENT	ENABLED, DISABLED		Whether event record or not

Metering and EasyLogic Operand

LCD display Item	Description
W1_C_IA, IB, IC	Winding#1 A, B, C Phase compensation current Secondary magnitude, angle
W2_C_IA, IB, IC	Winding#2 A, B, C Phase compensation current Secondary magnitude, angle
W3_C_IA, IB, IC	Winding#3 A, B, C Phase compensation current Secondary magnitude, angle
DIFF_IA, IB, IC	A, B, C Phase differential current Secondary magnitude
DIFF2_IA, IB, IC	A, B, C Phase 2 harmonics differential current Secondary magnitude
DIFF5_IA, IB, IC	A, B, C Phase 5 harmonics differential current Secondary magnitude
R_IA, IB, IC	A, B, C Phase restraint current Secondary magnitude
50/87_PKP	Current instantaneous/percent differential protection Pickup OR
50/87_PKP_A, B, C	Current instantaneous/percent differential protection A, B, C Phase Pickup
50/87_OP	Current instantaneous differential protection operation OR
50/87_OP_A, B, C	Current instantaneous differential protection A, B, C phase operation
87T_OP	Current percent differential protection operation OR
87T_OP_A, B, C	Current percent differential protection A, B, C phase operation

3.2.2 Phase/Ground Overcurrent Protection (50/51, 50N/51N)

Phase/Ground overcurrent protection is consisted of instantaneous/definite time phase overcurrent(50_1, 50_2), inverse time phase overcurrent(51), instantaneous/definite time ground overcurrent(50N_1, 50N_2), inverse time ground overcurrent (51N). Can embody 3 steps protection property if mix independent 3 elements by phase/ground element. Minimum operating time of instantaneous/definite time element is below 40msec. Inverse time element property curve is consisted of IEC class 4, IEEE/ANSI class 7, KEPCO class 3. Detection current of phase overcurrent protection uses CT secondary current that is inputted to relay independently of compensating current that use in percent differential protection.
Input current of ground overcurrent protection element can get from ground protection CT or residual connection of 3phase CT.

Detailed contents for property curve expect to refer to Appendix C. Time Characteristics Curves.

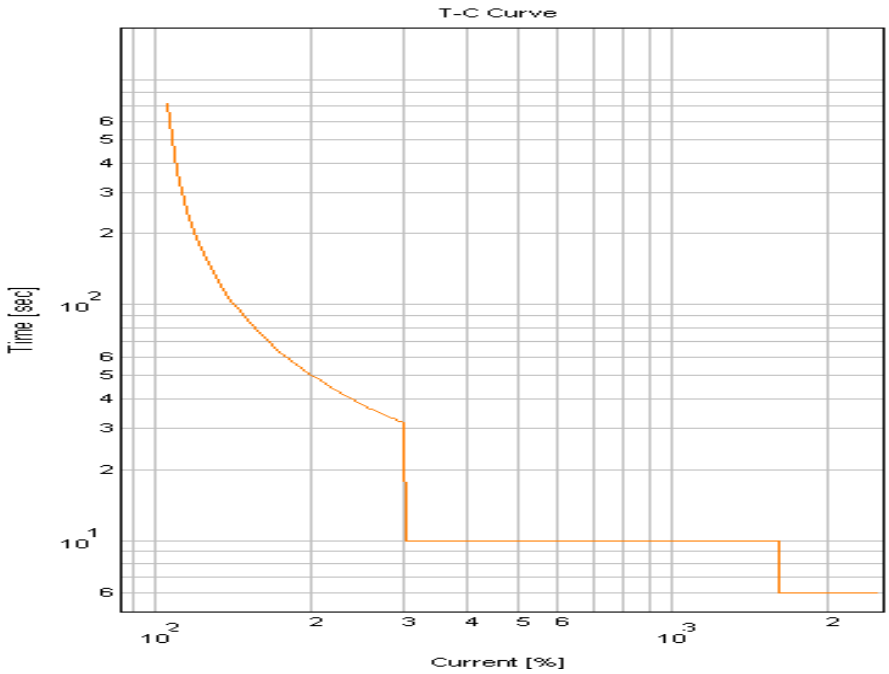


Figure 3-4 Phase/Ground overcurrent protection operating characteristic

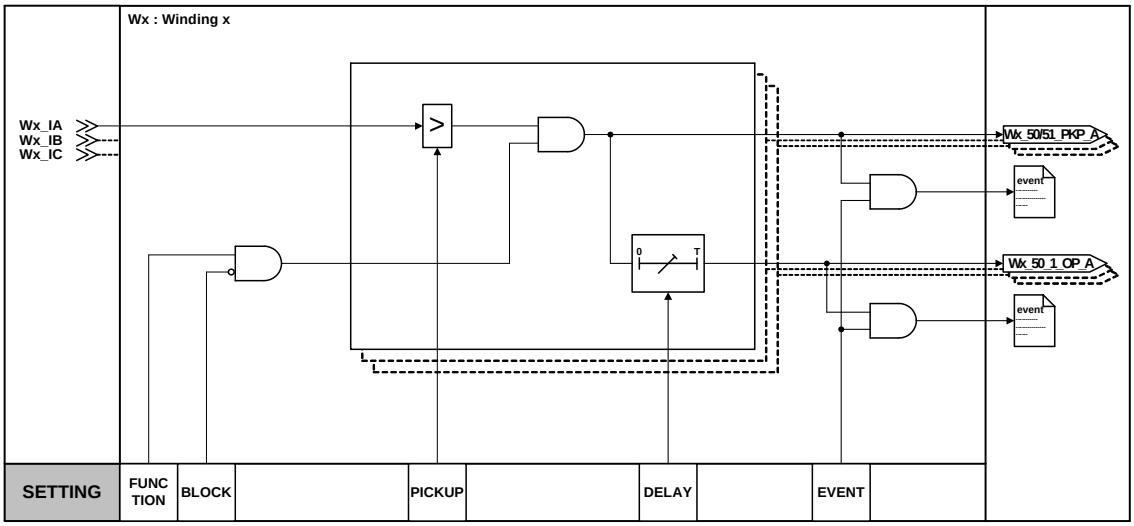


Figure 3-5 Instantaneous/definite time phase overcurrent protection operating characteristic

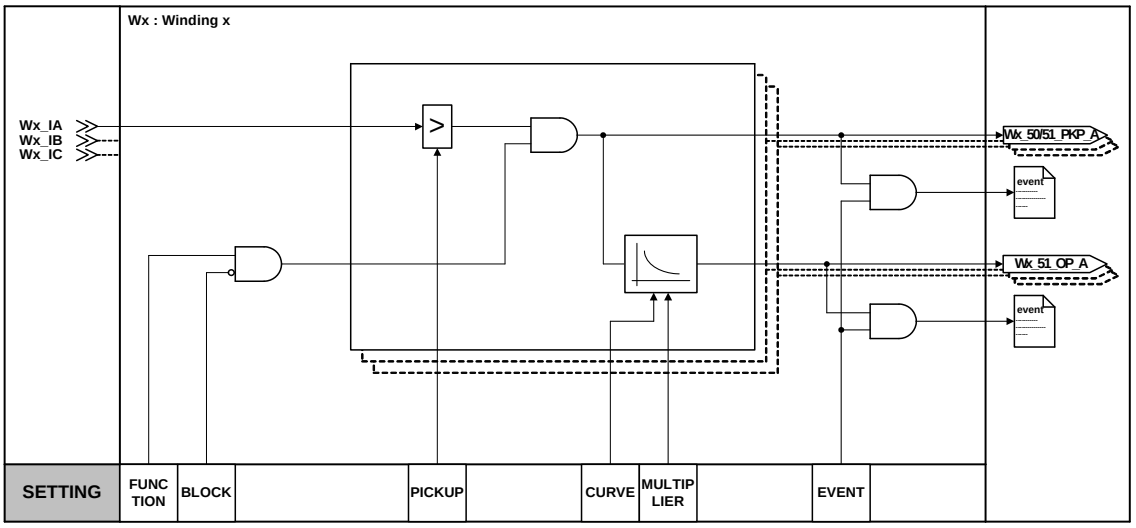


Figure 3-6 Time delay phase overcurrent protection operating characteristic

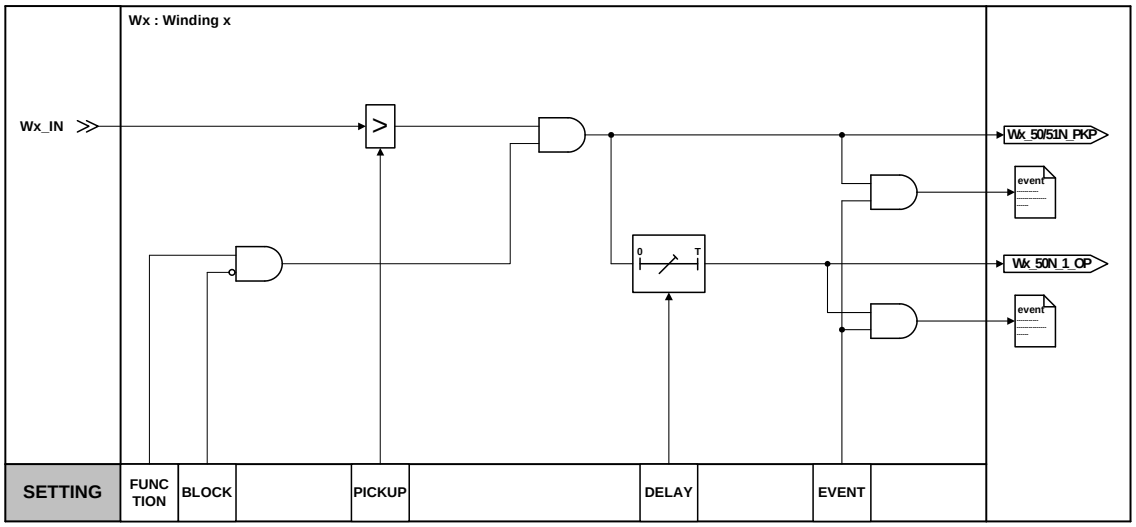


Figure 3-7 Instantaneous/definite time ground overcurrent protection operating characteristic

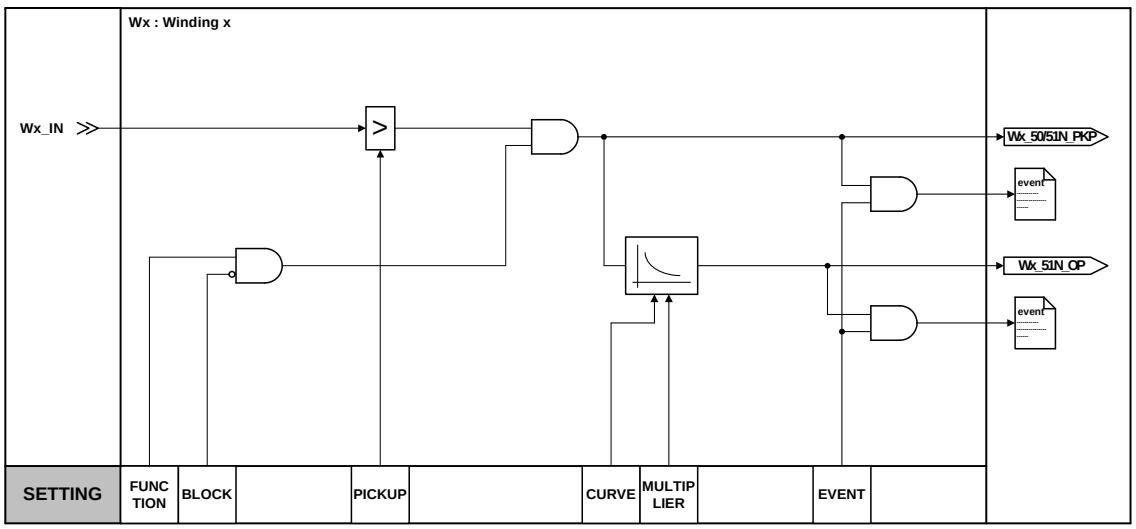


Figure 3-8 Time delay ground overcurrent protection operating characteristic

SETTING/ PROTECT#1~#4/ Winding#1~#3/ IOC1(Wx_50_1), IOC2(Wx_50_2)
SETTING/ PROTECT#1~#4/ Winding#1~#3/ IOCG1(Wx_50N_1), IOCG2(Wx_50N_2)

Setting Item	Step	Unit	Description
1. FUNCTION	ENABLED, DISABLED		Whether function use or not
2. PICKUP	0.50 ~ 100.00 (0.01)	A	Pickup current
3. DELAY	0.00 ~ 60.00	sec	Operating delay time
4. BLOCK	EasyLogic operand		Protection blocking condition
5. EVENT	ENABLED, DISABLED		Whether event record or not

SETTING/ PROTECT#1~#4/ Winding#1~#3/ TOC(Wx_51)
SETTING/ PROTECT#1~#4/ Winding#1~#3/ TOCG(Wx_51N)

Setting Item	Step	Unit	Description
1. FUNCTION	ENABLED, DISABLED		Whether function use or not
2. CURVE	IEC_NI, …, KDNI		Inverse curve setting. IEC_NI : IEC Normal Inverse IEC_VI : IEC Very Inverse IEC_EI : IEC Extremely Inverse IEC_LI : IEC Long Inverse ANSI_I : ANSI Inverse ANSI_SI: ANSI Short Inverse ANSI_LI: ANSI Long Inverse ANSI_MI: ANSI Moderately Inverse ANSI_VI: ANSI Very Inverse ANSI_EI :ANSI Extremely Inverse ANSI_DI : ANSI Definite Inverse KNI : KEPCO Normal Inverse KVI : KEPCO Very Inverse KDNI:KEPCO Definite Normal Inverse
3. PICKUP	0.50 ~ 100.00 (0.01)	A	Pickup current
4. MULTIPLIER	0.01 ~ 10.00 (0.01)		Time Multiplier
4. BLOCK	EasyLogic operand		Protection blocking condition
5. EVENT	ENABLED, DISABLED		Whether event record or not

Metering and EasyLogic Operand

LCD display Item	Description
Wx_50/51_PKP	Winding#x Phase overcurrent protection Pickup OR
Wx_50/51_PKP_A, B, C	Winding#x Phase overcurrent protection A, B, C Phase Pickup
Wx_50_1_OP	Winding#x Instantaneous/definite time phase overcurrent protection 1 operating OR
Wx_50_1_OP_A, B, C	Winding#x Instantaneous/definite time phase overcurrent protection 1 A,B,C Phase operating
Wx_50_2_OP	Winding#x Instantaneous/definite time phase overcurrent protection 2 operating OR
Wx_50_2_OP_A, B, C	Winding#x Instantaneous/definite time phase overcurrent protection 2 A, B, C Phase operating
Wx_51_OP	Winding#x Time delay phase overcurrent protection operating OR
Wx_51_OP_A, B, C	Winding#x Time delay phase overcurrent protection A, B, C Phase operating
Wx_50/51N_PKP	Winding#x Ground overcurrent protection Pickup OR
Wx_50N_1_OP	Winding#x Instantaneous/definite time ground overcurrent protection 1

	operating
Wx_50N_2_OP	Winding#x Instantaneous/definite time ground overcurrent protection 2 operating
Wx_51N_OP	Winding#x Time delay ground overcurrent protection operating

3.2.3 Negative Sequence Overcurrent Protection (46, 46T)

Negative sequence overcurrent protection element is applied to detect unbalance fault that ground overcurrent protection element does not detect. Negative sequence overcurrent protection element have same protection elements of instantaneous/definite time 2, inverse time 1 as phase/ground overcurrent protection (50/51, 50N/51N) element. Pickup current (I2) of negative sequence overcurrent protection is

$I2 = \frac{1}{3}(\dot{I}_A + a^2\dot{I}_B + a\dot{I}c)$, ABC phase rotation.

Negative sequence overcurrent protection that ***TRANSFORMER/PHS COMP*** setting is INTERNAL in transformer only in occasion negative sequence current metering and negative sequence overcurrent protection runs.

Minimum operating time of instantaneous/definite time element is below 40msec. Inverse time element property curve is consisted of IEC class 4, IEEE/ANSI class 7, KEPCO class 3.

Detailed contents for property curve expect to refer to Appendix C. Time Characteristics Curves.

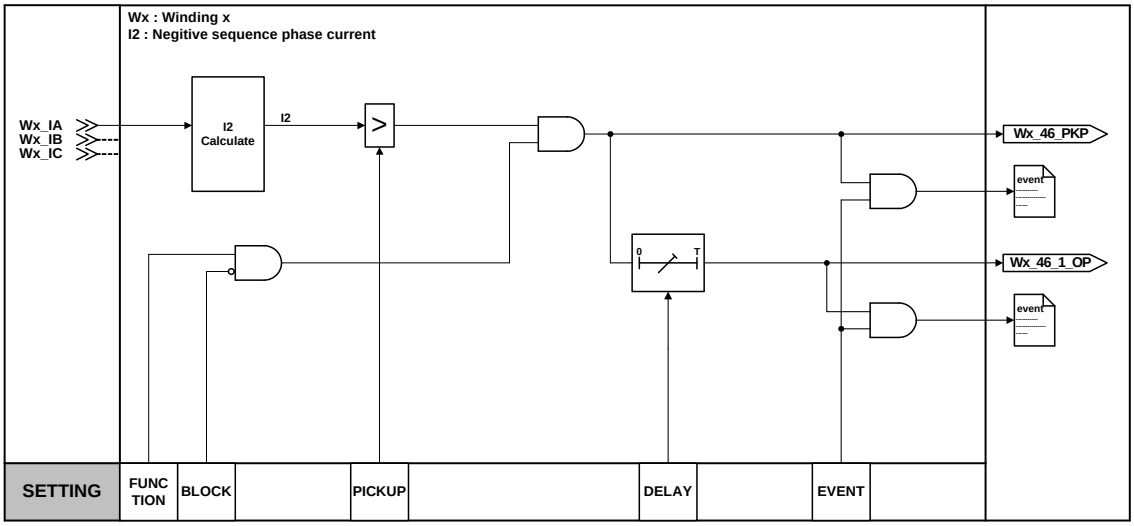


Figure 3-9 Instantaneous/definite time negative sequence overcurrent protection operating characteristic

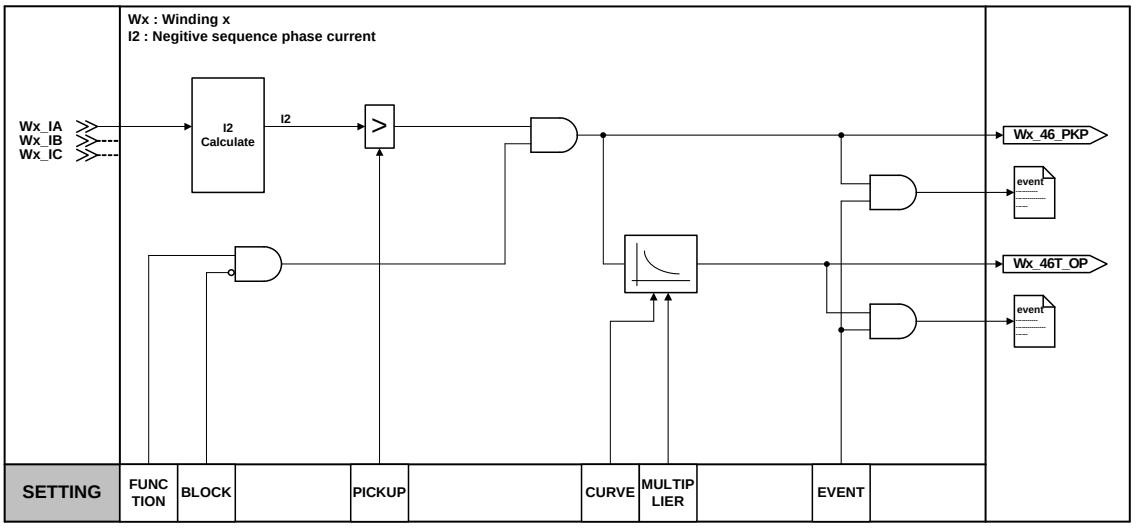


Figure 3-10 Time delay negative sequence overcurrent protection operating characteristic

SETTING/ PROTECT#1~#4/ Winding#1~#3/ NSOC1(Wx_46_1)/NSOC2(Wx_46_2)

Setting Item	Step	Unit	Description
1. FUNCTION	ENABLED, DISABLED		Whether function use or not
2. PICKUP	0.50 ~ 100.00 (0.01)	A	Negetive sequence current Pickup
3. DELAY	0.00 ~ 60.00	sec	Operation delay time
4. BLOCK	EasyLogic operand		Protection blocking condition
5. EVENT	ENABLED, DISABLED		Whether event record or not

SETTING/ PROTECT#1~#4/ Winding#1~#3/ TNSOC(Wx_46T)

Setting Item	Step	Unit	Description
1. FUNCTION	ENABLED, DISABLED		Whether function use or not
2. CURVE	IEC_NI, …, KDNI		Inverse curve setting. Is equal with phase overcurrent protection element.
3. PICKUP	0.50 ~ 100.00 (0.01)	A	Negetive sequence current Pickup
4. MULTIPLIER	0.01 ~ 10.00 (0.01)		Time Multiplier
4. BLOCK	EasyLogic operand		Protection blocking condition
5. EVENT	ENABLED, DISABLED		Whether event record or not

Metering and EasyLogic Operand

LCD display Item	Description
Wx_I2	Winding#x Negative sequence Secondary current magnitude, angle
Wx_46_PKP	Winding#x Negative sequence overcurrent protection Pickup OR
Wx_46_1_OP	Winding#x Instantaneous/definite time negative sequence overcurrent protection 1 operation
Wx_46_2_OP	Winding#x Instantaneous/definite time negative sequence overcurrent protection 2 operation
Wx_46T_OP	Winding#x Time delay negative sequence overcurrent protection operation

3.2.4 Restricted ground fault protection(87G)

Because restricted ground fault protection element is small magnitude of fault current, can not detect by percent differential protection element(87T). Near these occasion transformer grounding point winding more between to microscopic grounding fault detection such as short circuit apply.

Differential current used to restricted ground fault protection element is difference of three-phase current vector sum (3I0) by winding and CT current (Ig) placed in GND. Restraint current uses maximum value of three-phase current. Restricted ground fault protection element is acting definite time element according to ratio setting of restraint current (Imax) and differential current (Igd).

Restricted ground fault protection phase CT ratio and ground ground CT ratio slipway when differ correct should. CT Ratio setting wants to refer ***PHS CT RATIO/GND CT RATIO*** by winding of transformer.

3Phase current vector sum, $3I0 = \dot{I}_A + \dot{I}_B + \dot{I}c$

Ground point CT Ratio compensation, $I^*g = (PHS_CT_RATIO / GND_CT_RATIO) * Ig$ Ig: Ground point CT current

Differential current, $Igd = |3I0 - I^*g|$

Restraint current, $\mathrm{Im}ax = MAX(I_A, I_B, I_C)$

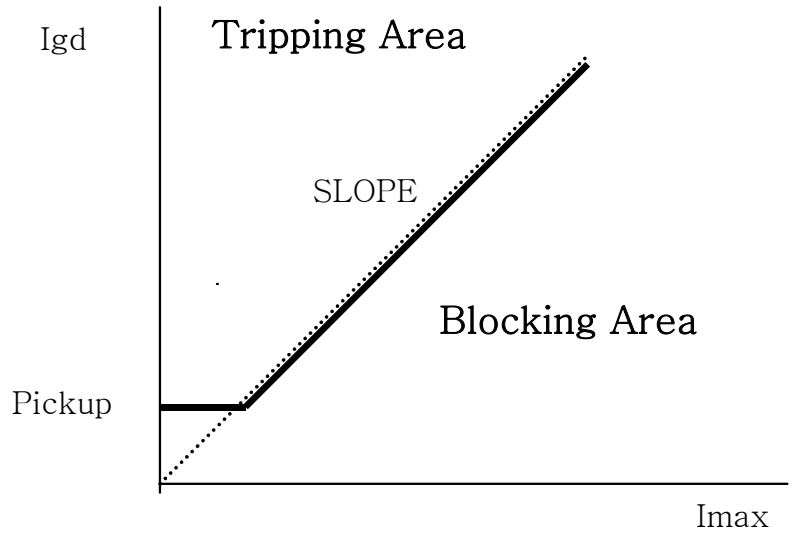


Figure 3-11 Restricted ground fault protection characteristic

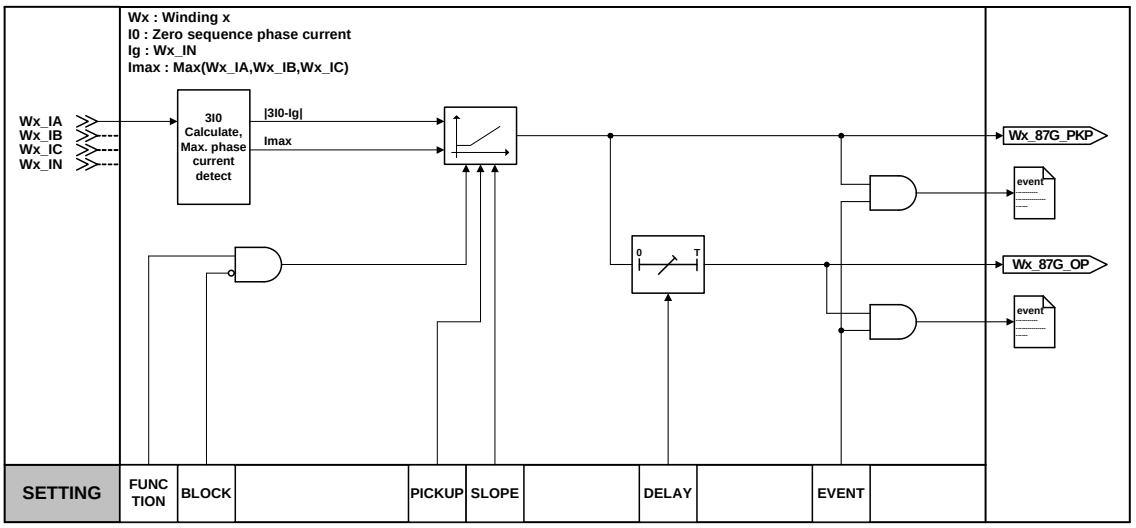


Figure 3-12 Restricted ground fault protection operation characteristic

SETTING/ PROTECT#1~#4/ Winding#1~#3/ GND DIFF(Wx_87G)

Setting Item	Step	Unit	Description
1. FUNCTION	ENABLED, DISABLED		Whether function use or not
2. PICKUP	0.50 ~ 100.00 (0.01)	A	Ground differential current Pickup
3. SLOPE	5 ~ 100% (1)	%	Operating ratio (Igd/Imax)*100
4. DELAY	0.00 ~ 60.00	sec	Operation delay time
5. BLOCK	EasyLogic operand		Protection blocking condition
6. EVENT	ENABLED, DISABLED		Whether event record or not

Metering and EasyLogic Operand

LCD display Item	Description
Wx_I0	Winding#x zero sequence Primary current magnitude, angle
Wx_87G_PKP	Winding#x restricted ground fault protection Pickup
Wx_87G_OP	Winding#x restricted ground fault protection operation

3.2.5 Overvoltage Protection(59)/Undervoltage Protection(27)

Overvoltage protection element is single phase protection element that is consisted of OV1 (59_1) and OV2 (59_2) acting by definite/inverse time element that act by definite time element. Inverse time dynamic characteristic is equal with property of induction type overvoltage relay. Relay acts in case of inputted phase voltage is more than pickup. Detailed contents for property curve expect to refer to Appendix C. Time Characteristics Curves

Undervoltage protection element is single phase protection element that is consisted of UV1 (27_1) and UV2 (27_2) acting by definite/inverse time element that act by definite time element. Inverse time dynamic characteristic is equal with property of induction type overvoltage relay. Relay acts in case of inputted phase voltage is below than pickup. Detailed contents for property curve expect to refer to Appendix C. Time Characteristics Curves

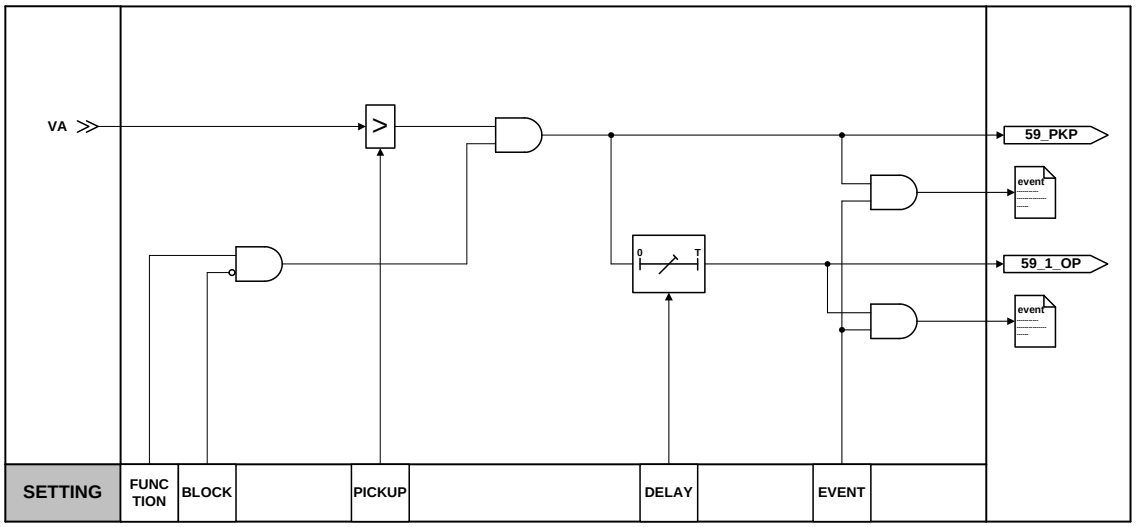


Figure 3-13 Definite time overvoltage protection operating characteristic

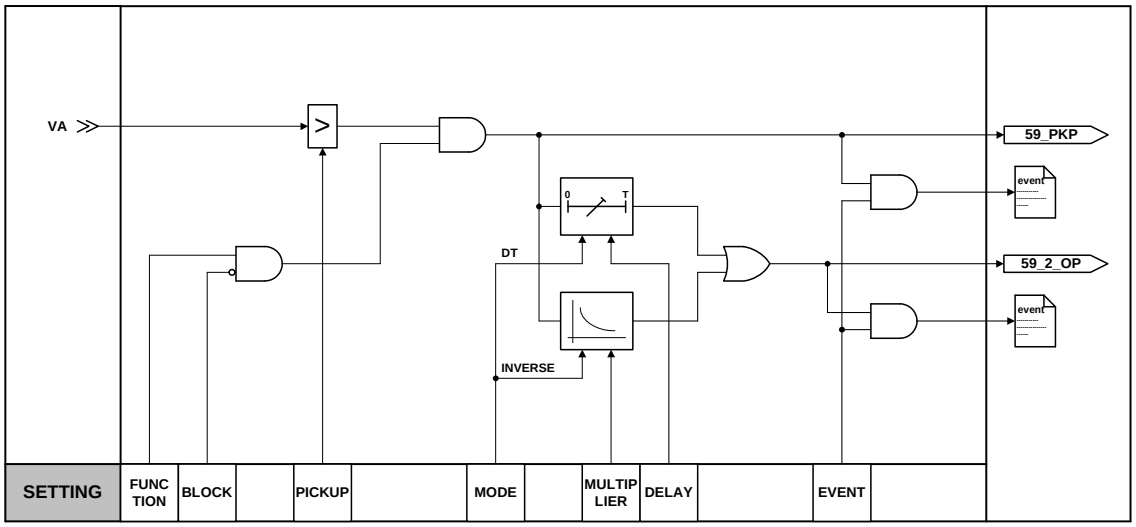


Figure 3-14 Inverse time overvoltage protection operating characteristic

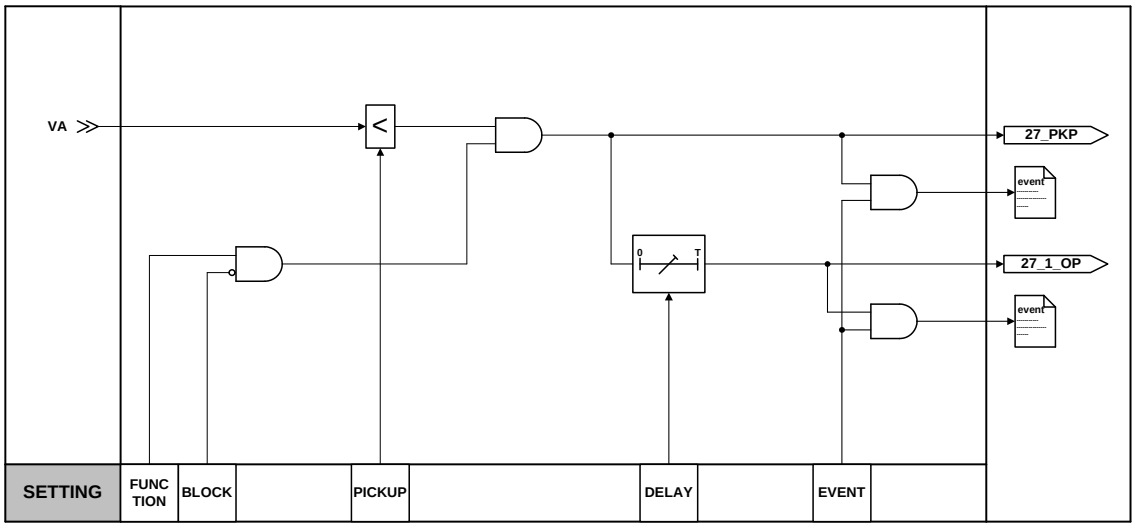


Figure 3-15 Definite time undervoltage protection operating characteristic

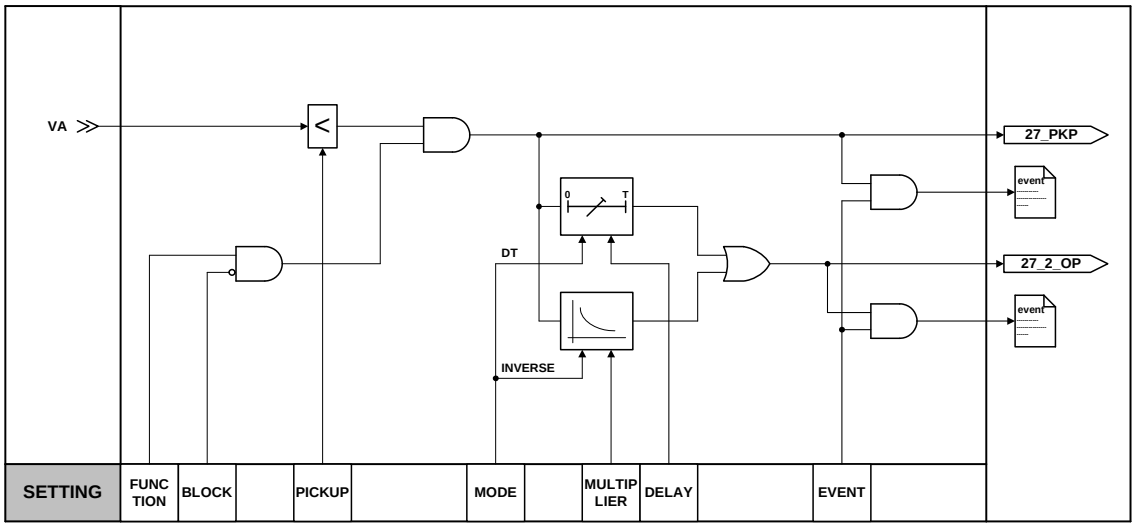


Figure 3-16 Inverse time undervoltage protection operating characteristic

SETTING/ PROTECT#1~#4/ OV(59)/ OV1(59_1)
SETTING/ PROTECT#1~#4/ UV(27)/ UV1(27_1)

Setting Item	Step	Unit	Description
1. FUNCTION	ENABLED, DISABLED		Whether function use or not
2. PICKUP	5 ~ 170 (1)	V	Voltage Pickup
4. DELAY	0.00 ~ 60.00	sec	Operation delay time
5. BLOCK	EasyLogic operand		Protection blocking condition
6. EVENT	ENABLED, DISABLED		Whether event record or not

SETTING/ PROTECT#1~#4/ OV(59)/ OV2(59_2)
SETTING/ PROTECT#1~#4/ UV(27)/ UV2(27_2)

Setting Item	Step	Unit	Description
1. FUNCTION	ENABLED, DISABLED		Whether function use or not
2. MODE	DT, INVERSE		Operating Mode setting DT : Definite time INVERSE : Inverse time
3. PICKUP	5 ~ 170 (1)	V	Voltage Pickup
4. DELAY	0.00 ~ 60.00	sec	Operation delay time
4. MULTIPLIER	0.01 ~ 10.00(0.01)		Time Multiplier
5. BLOCK	EasyLogic operand		Protection blocking condition
6. EVENT	ENABLED, DISABLED		Whether event record or not

Metering and EasyLogic Operand

LCD display Item	Description
VA	Single phase primary voltage magnitude, angle
59_PKP	Single phase Overvoltage Pickup OR
59_1_OP	Single phase Overvoltage 1 Operation OR
59_2_OP	Single phase Overvoltage 2 Operation OR
27_PKP	Single phase Undervoltage Pickup OR
27_1_OP	Single phase Undervoltage 1 Operation OR
27_2_OP	Single phase Undervoltage 2 Operation OR

3.2.6 Overexcitation protection(V/Hz, 24)

Overexcitation protection element is used to prevent damage of transformer by overexcitation. It becomes overexcitation driving because saturated phenomenon happens and excitation current enlarges in case of drive transformer more than rated voltage, or drives by rated frequency low. Life-time of transformer by overheats of malfunction and inside structure of percent differential relay at overexcitation driving is shortened, and power dissipation is increased. There are 2 overexcitation protection elements that act by definite time about single-phase voltage input to relay. Voltage uses single-phase voltage input(A-phase). To ***FREQUENCY***, ***PHS PT SEC*** setting of POWER SYSTEM must be confirmed when set pickup.

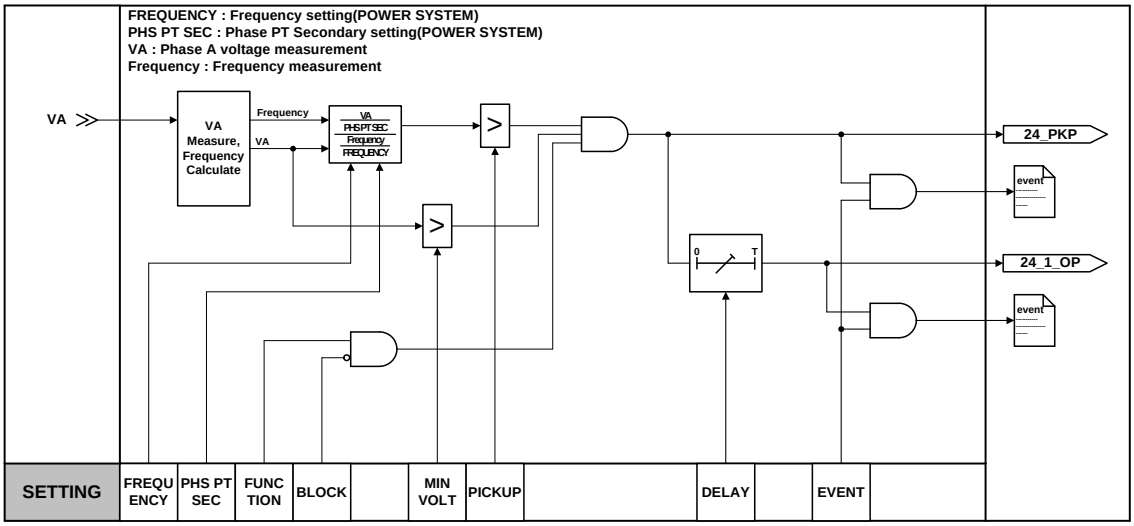


Figure 3-17 Overexcitation protection operating characteristic

SETTING/ PROTECT#1~#4/ V/Hz1(24_1), V/Hz2(24_2)

Setting Item	Step	Unit	Description
1. FUNCTION	ENABLED, DISABLED		Whether function use or not
2. PICKUP	1.00 ~ 4.00(0.01)	V/Hz	V/Hz Pickup (Input voltage/rated voltage)/(Frequency metering/rated frequency)
3. MIN VOLT	5 ~ 50 (1)	V	Minimum operating voltage setting
4. DELAY	0.00 ~ 180.00	sec	Operation delay time
5. BLOCK	EasyLogic operand		Protection blocking condition
6. EVENT	ENABLED, DISABLED		Whether event record or not

Metering and EasyLogic Operand

LCD display Item	Description
FREQUENCY	Single phase voltage frequency
24_PKP	Overexcitation protection Pickup OR
24_1_OP	Overexcitation protection 1 operation
24_2_OP	Overexcitation protection 2 operation

3.2.7 Circuit Breaker Fail Protection(50BF)

After circuit breaker fail protection passes fault exclusion expectation time after relay displays trip signal to circuit breaker for fault origination, in case current passes continually, it is the second protection element that do it so that may act circuit breaker of high position system by circuit breaker fail signal and does so that remove fault.

It operates when phase current (W1_IA, W1_IB, W1_IC) is over pickup after expectation trip delay time passes moving to set Trip point of contact, relay acts. Trip contact output setting is possible to CONTACT OUTPUT#1 ~ CONTACT OUTPUT#6. Circuit breaker fail protection is applied only to transformer primary winding.

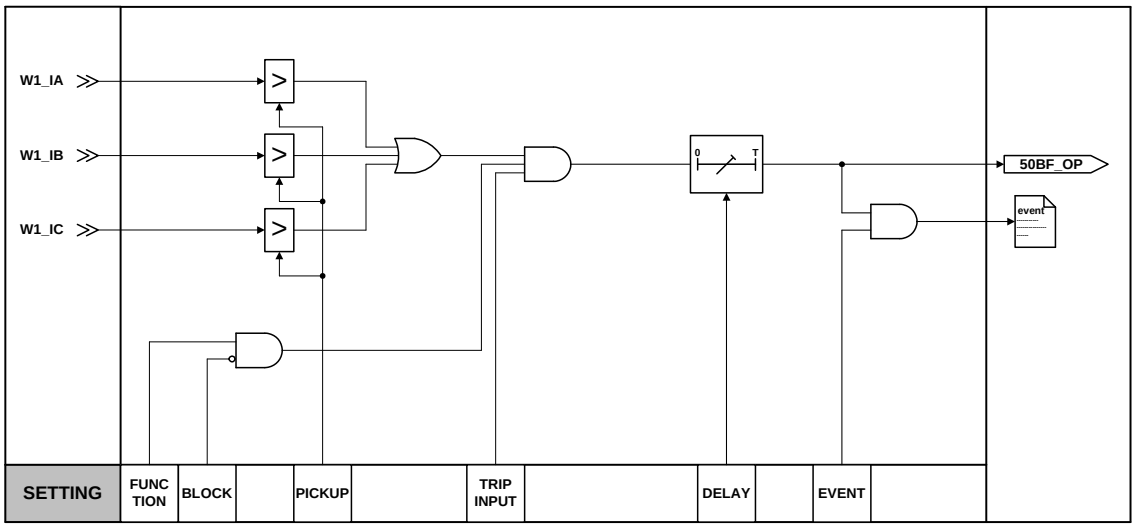


Figure 3-18 Circuit breaker fail protection operating characteristic

SETTING/ PROTECT#1~#4/ CBF(50BF)

Setting Item	Step	Unit	Description
1. FUNCTION	ENABLED, DISABLED		Whether function use or not
2. TRIP INPUT	CONT OUT#1 ~ #6		Trip input contact
3. PICKUP	0.50 ~ 2.50(0.01)	A	Current Pickup
4. DELAY	0.00 ~ 60.00	sec	Function start delay time after Trip output
5. BLOCK	EasyLogic operand		Protection blocking condition
6. EVENT	ENABLED, DISABLED		Whether event record or not

Metering and EasyLogic Operand

LCD display Item	Description
50BF_OP	Circuit breaker fail protection operation

3.2.8 Cold Load Pickup(COLDLD)

Inrush current when it is line, transformer and reactor etc are injected can lead to malfunction to exceed setting value of time of normal operation of protection element. Can achieve most suitable protection that Cold Load Pickup element applies setting value of protection element high during setup time from injection detecting closing time and stationary state applies proper form setting value. Relay has operation delay time and acts in case of it is below size that phase current (W1_IA, W1_IB, W1_IC) is set all, and relay has reset delay time and returns in case of it is more than size that current more than 1 among phase current is set.

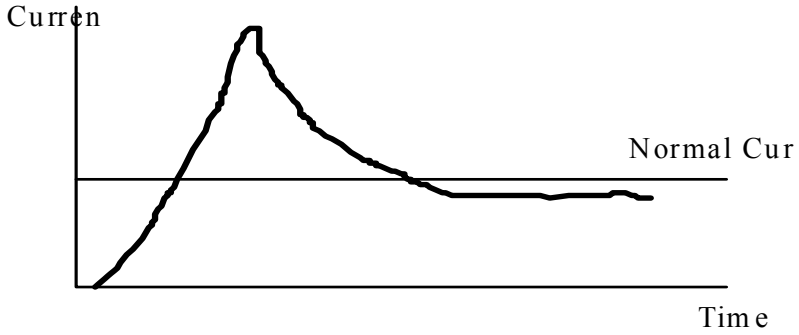


Figure 3-19 Cold Load Pickup current shape

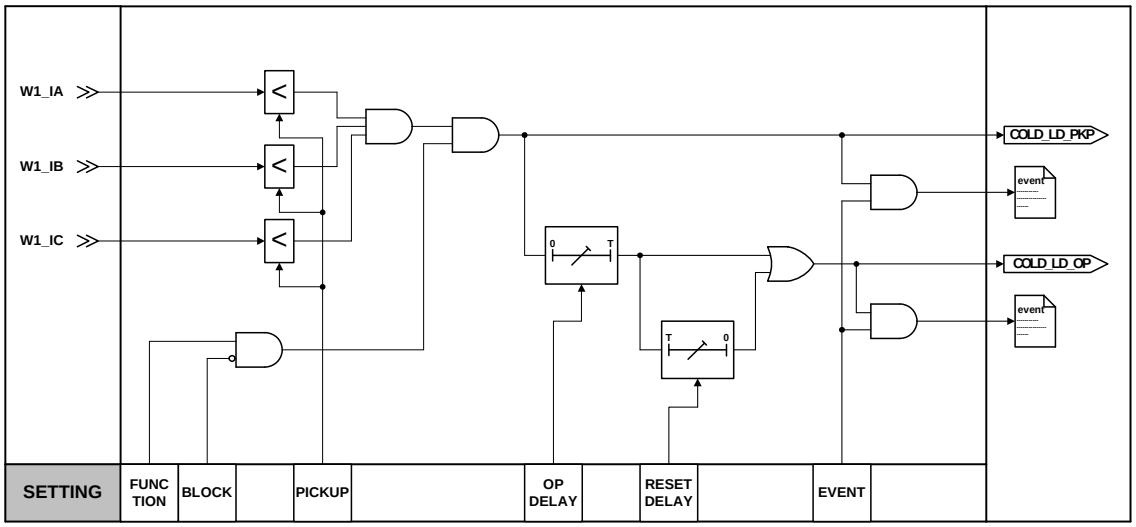


Figure 3-20 Cold Load Pickup operating characteristic

SETTING/ PROTECT#1~#4/ COLD LD

Setting Item	Step	Unit	Description
1. FUNCTION	ENABLED, DISABLED		Whether function use or not
2. PICKUP	0.10 ~ 5.00 (0.01)	A	Cold Load Pickup current
3. OP DELAY	0~1000(1)	sec	Operation delay time
4. RESET DELAY	0~1000(1)	sec	Reset delay time
5. BLOCK	EasyLogic operand		Protection blocking condition
6. EVENT	ENABLED, DISABLED		Whether event record or not

Metering and EasyLogic Operand

LCD display Item	Description
COLD_LD_PKP	Cold Load Pickup detect Pickup
COLD_LD_OP	Cold Load Pickup detect Operation

3.2.9 Inrush Detection

Inrush current detection element is used into expenditure that prevent malfunction of protection element from inrush current that occur when it is pressurization of long-distance line, transformer, reactor etc. When inrush current detection element is more than size that fundamental wave current (I1f) is set, and ratio of 2 harmonics current (I2f) and fundamental wave current is more than setting value, it is acting instantaneous/definite time element. Relay can control protection element operation during inrush current detection through 'Block' setting that is to each protection element. Inrush detection is applied only to transformer primary winding.

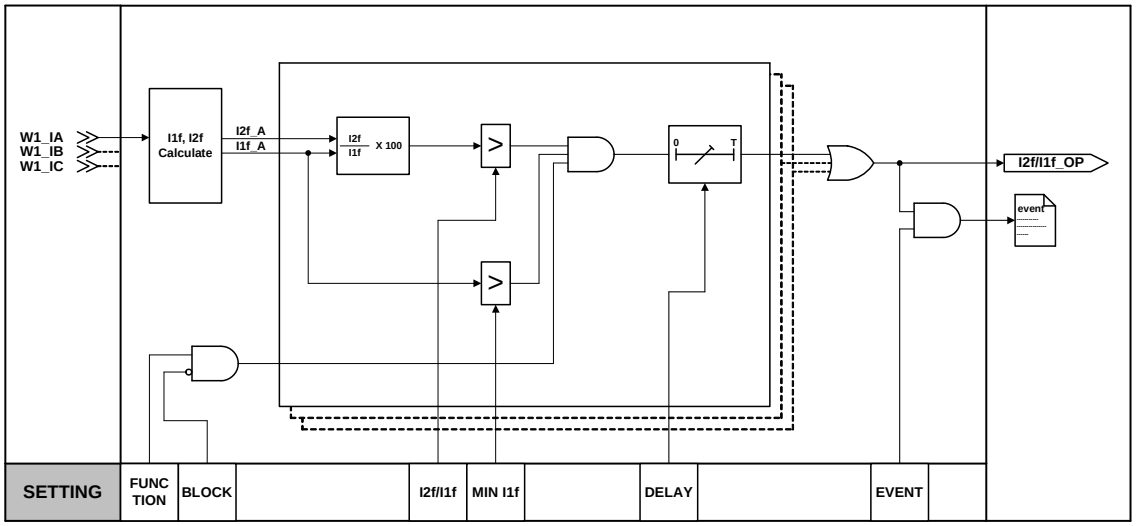


Figure 3-21 Inrush current detection operating characteristic

SETTING/ PROTECT#1~#4/ INRUSH

Setting Item	Step	Unit	Description
1. FUNCTION	ENABLED, DISABLED		Whether function use or not
2. I2f/I1f	10 ~ 100% (1)	%	(2 harmonics current / fundamental wave current)*100
3. MIN I1f	0.10 ~ 2.50(0.01)	A	fundamental wave minimum operating current
4. DELAY	0.00 ~ 60.00	sec	Operating time delay
5. BLOCK	EasyLogic operand		Protection blocking condition
6. EVENT	ENABLED, DISABLED		Whether event record or not

Metering and EasyLogic Operand

LCD display Item	Description
I2f/I1f_OP	Inrush current detection operation

3.3 Subsidiary Function

3.3.1 Record

Event/Fault record

Relay can record event & fault recording up to 1024. All events record with information occurrence time by resolution of 1msec.
Event/Fault items are power On/Off, protection operation status, digital input/output status, CB control, setting change, monitoring/diagnostic status, event data clear, waveform data clear, circuit breaker output counter change etc. When it is protection element operation status change, relay records together fault information.

- Single Phase voltage frequency, Secondary magnitude
- Winding#1 current A,B,C Phase Secondary magnitude
- Winding#2 current A,B,C Phase Secondary magnitude
- Winding#3 current A,B,C Phase Secondary magnitude
- A, B, C Phase differential current Secondary magnitude
- A, B, C Phase restraint current Secondary magnitude
- Winding#1~#3 N-Phase current Secondary magnitude
- Winding#1~#3 current magnitude compensation Factor

Recorded events are listed up in LCD, and uploaded to PACManager ™ locally or by SCADA remotely. Event recording is kept even if power of relay is lost.

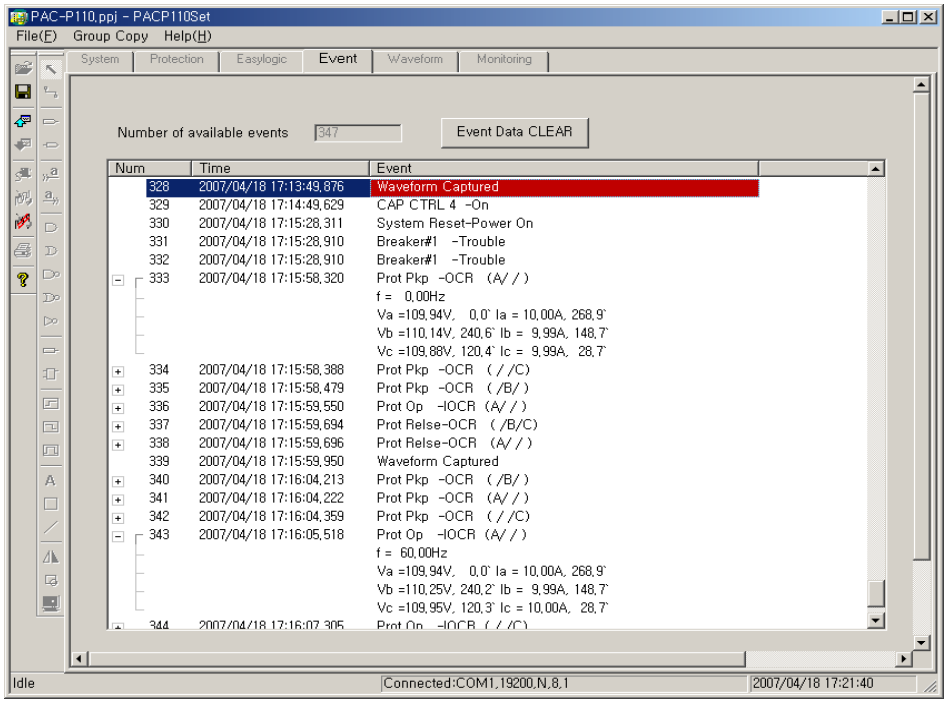


Figure 3-22 PACManager™ Event record

Waveform record

PAC-T100 has fault oscillograph function up to 8 waveforms with 32 sampling rate in non-volatile memory. Waveform has maximum 4 second recording time, where current, voltage, I/O contacts, protection element status are included.

Trigger condition to start recording can be I/O contact status change, protection element operation, and combination of internal logic configuration by EasyLogic™. And trigger position can be set in 0~99% location of total waveform size.

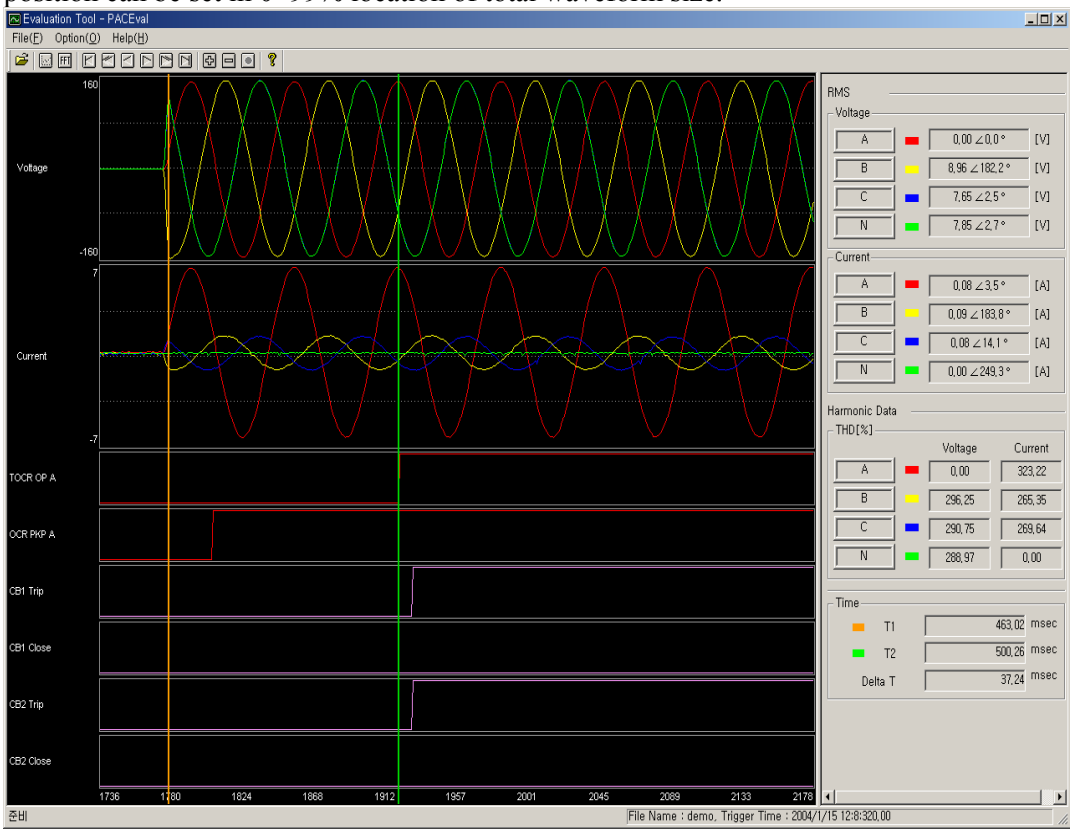


Figure 3-23 PACManager™ Waveform Analysis

Recorded waveform are listed up in LCD, and uploaded to PACManager ™ locally or by SCADA remotely. Waveform recording is kept even if power of relay is lost. Waveform is of COMTRADE file format so that it can be used for fault simulation with fault analysis and relay test equipment.

SETTING/ SYSTEM/ WAVEFORM RECORD

Setting Item	Step	Unit	Description
1. TYPE	8*80, 4*160, 2*320	Cycle	Waveform save number and capacity 8*50 : 8 Number, 80cycle
2. TRIGGER SRC	EasyLogic operand		Trigger source setting
3. TIRGGER POS	.0 ~ 99% (1)	%	Trigger position setting 40% : Waveform(40%) before trigger + waveform(60%) after trigger

3.3.2 Circuit breaker control

Relay can set up necessary setting to control circuit breaker 2 in SETTING/SYSTEM/BREAKER. ID of circuit breaker can set 12 characters. Each character should be set by English upper/lower-case, digit, spatial character registered to keyboard.
Each circuit breaker status can use one of 52a and 52b by contact input, or use everybody by contact input. Mark status of circuit breaker according to status of contact input in case of use contact input 1, relay marks status of circuit breaker according to 2 contact input statuses in case of use 2 by contact input. If use 2 digital inputs, can not control circuit breaker judging that problem is to point of contact connection of circuit breaker or circuit breaker if status of point of contact is same.
If status of CB is shown abnormally, confirm setting of contact input, activation of set contact input and connection status.

SETTING/ SYSTEM/ BREAKER#1~#2

Setting Item	Step	Unit	Description
1. FUNCTION	ENABLED, DISABLED		Whether function use or not
2. ID	ASCII		Circuit breaker ID, 12 character
3. TRIP PULSE	0.1 ~ 5.0 (0.1)	sec	Circuit breaker Trip control pulse
4. CLOSE PULSE	0.1 ~ 5.0 (0.1)	sec	Circuit breaker Close control pulse
5. 52a INPUT	NONE, CONT IN#1~CONT IN#16		Circuit breaker status(52A) contact input NONE : Circuit breaker status judgment by 52a
6. 52b INPUT	NONE, CONT IN#1~CONT IN#16		Circuit breaker status(52B) contact input NONE : Circuit breaker status judgment by 52b
7. KEY CTRL	ENABLED, DISABLED		Whether allowable local control for circuit breaker or not DISABLED : In local circuit breaker control prohibition

3.3.3 Trip circuit supervision (TCS)

This is alarming function is case the status of a contact input feedback from trip contact output keeps "0" status for more than 5 minutes. To monitor without CB open/close status information, CB aux contacts (52a, 52b) and resistance are required.

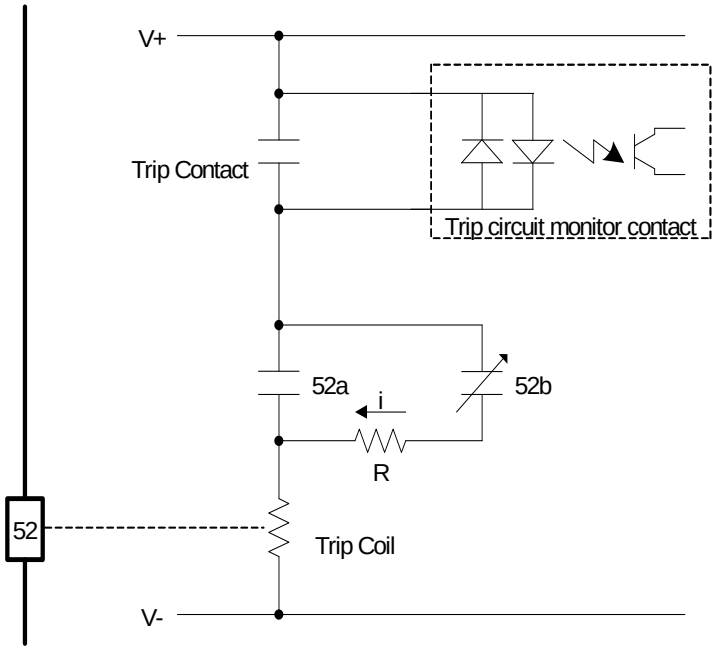


Figure 3-24 TCS circuit composition

SETTING/ SYSTEM/ TCS

Setting Item	Step	Unit	Description
1. FUNCTION	ENABLED, DISABLED		Whether function use or not
2. TRIP INPUT	CONTIN#1 ~CONT IN#16		Trip input

Metering and EasyLogic Operand

LCD display Item	Description
TCS_FAIL	TCS operation

3.3.4 Communication

SETTING/SYSTEM/COMMUNICATION sets that need in 2 RS485 communications that is situated to relay rear. Appear in 2 RS485 communication port settings and DNP3.0 protocol setting screen in case of DNP3.0 protocol is included product. Appear in 2 RS485 communication port setting screens in case of IEC60870-5-103 protocol is included product. COM2 is Modbus protocol dedicated, and protocol change is possible COM1.

Should do power Off/On certainly after store setting if change COM#1's protocol.(Reflection does not become by protocol that change power if do not Off/On.)

SETTING/ SYSTEM/ COM#1~#2

Setting Item	Step	Unit	Description
1. FUNCTION	ENABLED, DISABLED		Whether function use or not
2. BPS	300, 1200, 2400, 4800, 9600, 19200, 38400		Bit/sec
3. SLAVE ADDR	1~65534(1)	sec	Slave address Modbus, IEC60870-5-103 (1~254)
4. PROTOCOL	ModBus,DNP3.0 or Modbus,IEC60870-5-103	sec	Application communication protocol Differ according to ordering option

SETTING/ SYSTEM/ DNP3.0

Setting Item	Step	Unit	Description
1. TX DELAY	0 ~ 65000(1)	msec	Tx delay time
2. LINK CONFIRM	NEVER, ALWAYS, SOMETIMES		Link layer confirm
3. LINK RETRY	0~5(1)		Link layer retry count
4. LINK TIMEOUT	1 ~ 65000(1)	msec	Link layer timeout
5. SBO TIMEOUT	1 ~ 65000(1)	msec	SBO timeout
6. WR TIME INT	1 ~ 65000(1)	min	Write time interval
7. COLD RESTART	ENABLED, DISABLED	sec	Cold restart.

3.3.5 SYSTEM Time

System time may set in local or remote through communication.

SETTING/SYSTEM/RTC is used to change system time that is placed inside protective relay. Setting order is order year/month/day/hour:minute:second.
Select each item by left(<), right(>) key, and changes value by up(^), down(v) key. If press ENTER key, time is set.

SETTING/ SYSTEM/ RTC

Setting Item	Step	Unit	Description
YYYY	2000 ~ 2100(1)		Year
MM	01~12(1)		Month
DD	01~31(1)		Day
HH	00~23(1)		Hour
MM	00~59(1)		Minute
SS	00~59(1)		Second

4 Application example

4.1 Wiring and setting

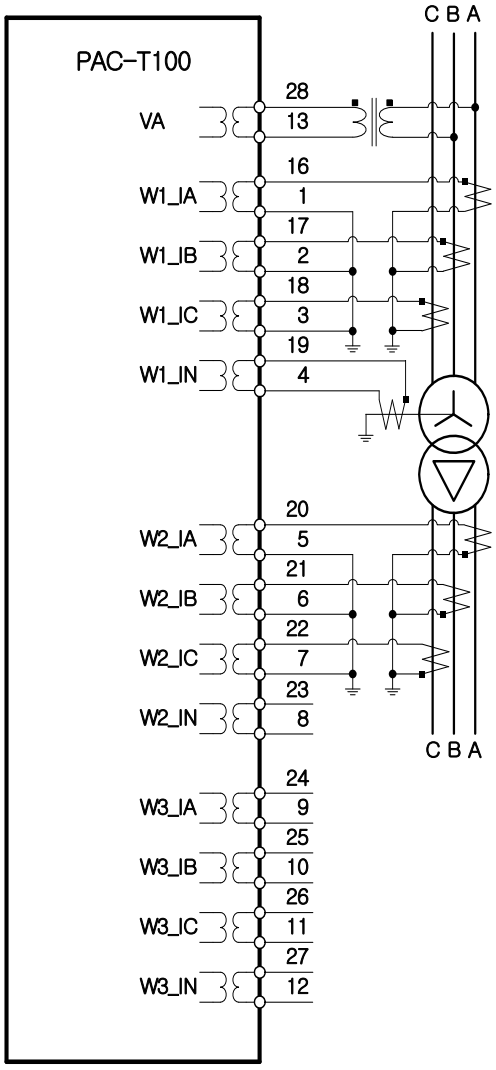


Table 4-1 Application example POWER SYSTEM setting

Power System	Setting	단위
1. FREQUENCY	60Hz	
2. PHS PT PRI	154000	V
3. PHS PT SEC	110	V
4. SET GROUP	GROUP#1	
Transformer		
1. TYPE	Y-D	
2. PHS COMP	INTERNAL	
3. W1-W2 PHS	30	◦ lag
3. W1-W3 PHS	--	◦ lag
Winding#1		
1. NORM VOLT	154.00	kV
2. RATED LOAD	60.00	MVA
3. PHS CT RATIO	400	: 5
4. GND CT RATIO	200	: 5
5. GROUNDING	YES	
Winding#2		
1. NORM VOLT	22.90	kV
2. RATED LOAD	60.00	MVA
3. PHS CT RATIO	2000	: 5
4. GND CT RATIO	500	: 5
5. GROUNDING	NO	

Figure 4-1 Application example two windings transformer wiring

Set SETTING/POWER SYSTEM like table 4-1 and inputs current/voltage.

4.2 Measurement

Current/Voltage input

Terminal	Input value
FREQUENCY	60Hz
VA	110
W1_IA	1.00 A, 0.0 º
W1_IB	2.00 A, 240.0 º
W1_IC	3.00 A, 120.0 º
W1_IN	1.00 A, 0.0 º
W2_IA	1.00 A, 180.0 º
W2_IB	2.00 A, 60.0 º
W2_IC	3.00 A, 300.0 º

Primary current/voltage/frequency/Sequence current display

Current/voltage magnitude reflects CT and PT Ratio setting by transformer winding and marks by primary current/voltage. Phase metering marks via winding#1 A-phase current.

- Voltage : (154000/110)*110 = **154000[V],0.0 º**
- Winding#1 A-phase current: (400/5)*1 = **80[A], 0.0 º**
- Winding#1 B-phase current: (400/5)*2 = **160[A], 240.0 º**
- Winding#1 C-phase current: (400/5)*3 = **240[A], 120.0 º**
- Winding#1 N-phase current: (200/5)*1 = **40[A], 0.0 º**
- Winding#2 A-phase current: (2000/5)*1 = **400[A], 180.0 º**
- Winding#2 B-phase current: (2000/5)*2 = **800[A], 60.0 º**
- Winding#2 C-phase current: (2000/5)*3 = **1200[A], 300.0 º**

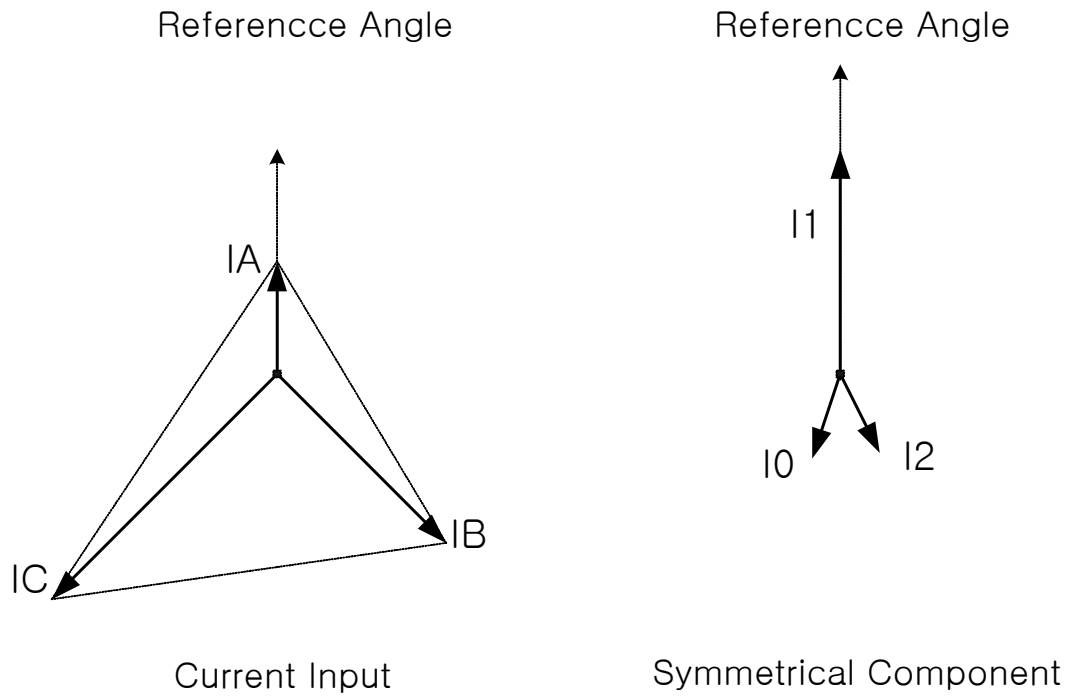


Figure 4-2 Sequence current

- Winding#1 zero sequence current, $I0 = \frac{1}{3}(\dot{I}_A + \dot{I}_B + \dot{I}_C)$:(400/5)*0.57 = **45.6[A],150.0 º**
- Winding#1 positive sequence current, $I1 = \frac{1}{3}(\dot{I}_A + a\dot{I}_B + a^2\dot{I}c)$:(400/5)*2 = 160[A], 0 º
- Winding#1 negative sequence current, $I2 = \frac{1}{3}(\dot{I}_A + a^2\dot{I}_B + a\dot{I}c)$:(400/5)*0.57= 45.6[A], 210 º

4.3 Current differential measurement

Current/Voltage input

Terminal	Input value
FREQUENCY	60Hz
VA	110
W1_IA	1.00 A, 0.0 º
W1_IB	1.00 A, 240.0 º
W1_IC	1.00 A, 120.0 º
W1_IN	0.50 A, 0.0 º
W2_IA	1.00 A, 150.0º
W2_IB	1.00 A, 30.0º
W2_IC	1.00 A, 270.0 º

Phase and ground current compensation

- Phase compensation reference winding: Δ winding(Winding#2)
- Phase compensation value: Θw1 = 0-(-30) = 30 °lag, Θw2 = 0-0 = 0
- Ground current remove(0, 0 Compensation Table reference)

$$\dot{I}_A^* = 1/\sqrt{3}\dot{I}_A - 1/\sqrt{3}\dot{I}_C$$
$$\dot{I}_B^* = 1/\sqrt{3}\dot{I}_B - 1/\sqrt{3}\dot{I}_A$$
$$\dot{I}_C^* = 1/\sqrt{3}\dot{I}_C - 1/\sqrt{3}\dot{I}_B$$

- Winding#1 phase compensation :
- Winding#2 phase compensation : $\dot{I}_A^* = \dot{I}_A, \dot{I}_B^* = \dot{I}_B, \dot{I}_C^* = \dot{I}_C$

Reference winding, magnitude compensation value

- Rated current calculate

$$I_{rated}[1] = \frac{60MVA}{\sqrt{3} \bullet 154kV} = 224.94A \quad , \quad I_{rated}[2] = \frac{60MVA}{\sqrt{3} \bullet 23kV} = 1506.13A$$

- CT margin ratio calculate(magnitude reference winding : winding#2)

$$I_{margin}[1] = \frac{80}{224.94} = 0.35 \quad , \quad I_{margin}[2] = \frac{400}{1506.13} = 0.27$$

- Magnitude compensation value calculate,

$$M[1] = \frac{154 \bullet 80}{23 \bullet 400} = 1.34 \quad , \quad M[2] = \frac{23 \bullet 400}{23 \bullet 400} = 1.000$$

Compensation current(Secondary)

If apply phase and magnitude compensation value, compensating current by winding is as following.

- Winding#1 A-Phase: 1/√3(1∠ 0°-1∠120°)*1.34 = **1.34[A],330.0°**
- Winding#1 B-Phase: 1/√3(1∠240°-1∠ 0°)*1.34 = **1.34[A],210.0°**
- Winding#1 C-Phase: 1/√3(1∠120°-1∠240°)*1.34 = **1.34[A], 90.0°**
- Winding#2 A-Phase: 1A*1*1.00 = **1.00[A], 150.0°**
- Winding#2 B-Phase: 1A*1*1.00 = **1.00[A], 30.0°**
- Winding#2 C-Phase: 1A*1*1.00 = **1.00[A], 270.0°**

Differential current/Restraint current

- A-Phase differential current: **0.34[A]**
- B-Phase differential current: **0.34[A]**

- C-Phase differential current: **0.34[A]**
- A-Phase restraint current: **1.17[A]**
- B-Phase restraint current: **1.17[A]**
- C-Phase restraint current: **1.17[A]**

4.4 Restricted ground fault protection measurement(Winding#1)

Current/Voltage input

Terminal	Input value
W1_IA	1.30 A, 0.0 º
W1_IB	1.00 A, 240.0 º
W1_IC	1.00 A, 120.0 º
W1_IN	0.50 A, 0.0 º

Ground point CT Ratio compensation

- $I^*g = (PHS_CT_RATIO / GND_CT_RATIO) * Ig$ = (400/200)*0.50 = **1.00[A], 0.0º**
- $3I0 = \dot{I}_A + \dot{I}_B + \dot{I}c$ = **0.30[A], 0.0º**

Differential current/Restraint current

- Differential current, $Igd = |3I0 - I^*g|$ = 1.00-0.30 = **0.70[A]**
- Restraint current, $\mathrm{Im}ax = MAX(I_A, I_B, I_C)$ = **1.30[A]**

5 Install and External connection

5.1 Dimensioned Drawings

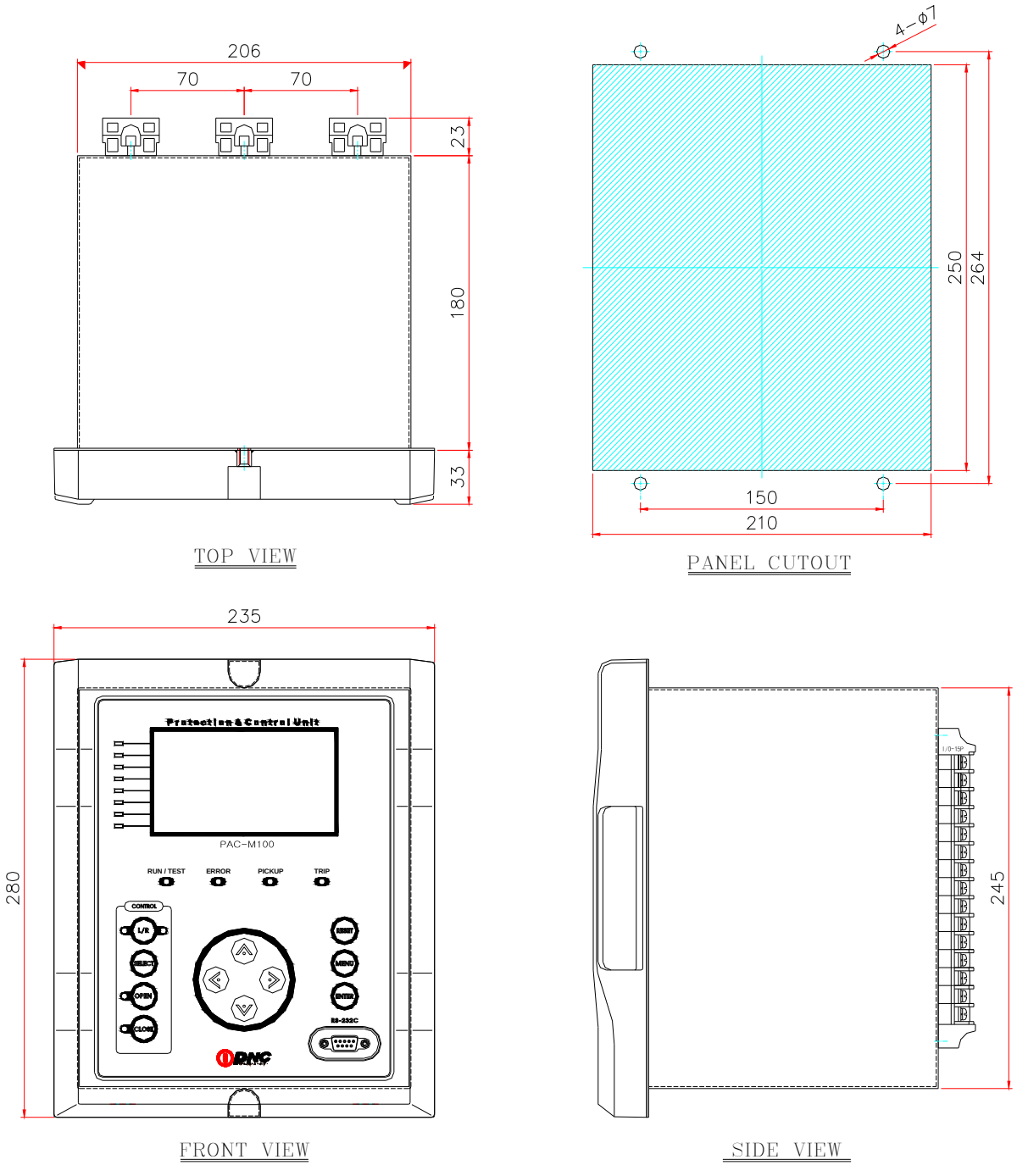
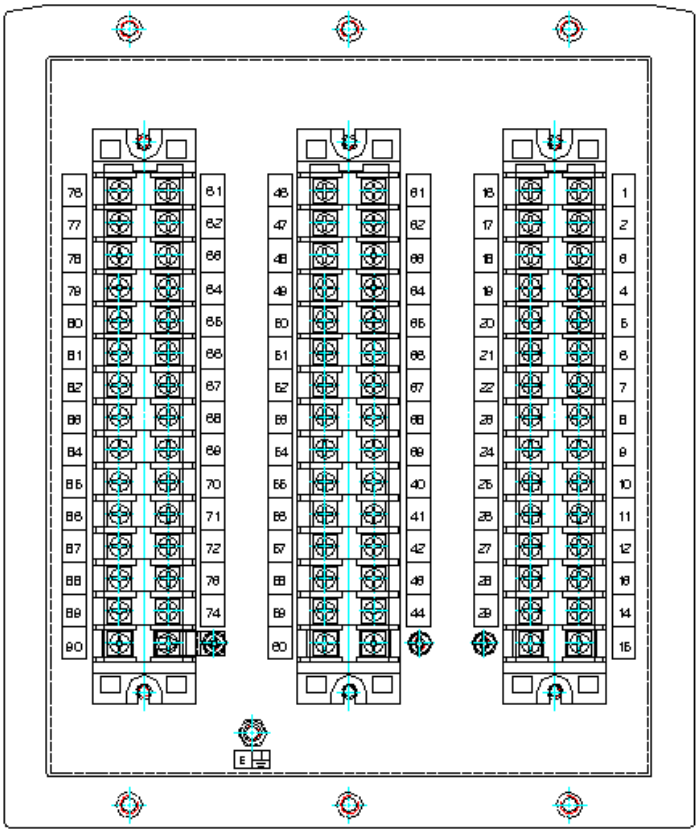


Figure 5-1 PAC-T100 Dimensioned Drawings

5.2 Rear terminal arrangement plan



REAR VIEW

Table 5-1 Terminal arrangement

76	TS1_COM	61	TS1_NO	46	DI1_COM	31	DI1_P	16	W1_IA+	1	W1_IA-
77	TS2_COM	62	TS2_NO	47	DI2_ COM	32	DI2_P	17	W1_IB+	2	W1_IB-
78	TS3_COM	63	TS3_NO	48	DI3_ COM	33	DI3_P	18	W1_IC+	3	W1_IC-
79	TS4_COM	64	TS4_NO	49	DI4_ COM	34	DI4_P	19	W1_IN+	4	W1_IN-
80	TS5_COM	65	TS5_NO	50	DI6_P	35	DI5_P	20	W2_IA+	5	W2_IA-
81	TS6_COM	66	TS6_NO	51	DI8_P	36	DI7_P	21	W2_IB+	6	W2_IB-
82	TS8_NO	67	TS7_NO	52	DI5_8_ COM	37	DI9_P	22	W2_IC+	7	W2_IC-
83	TS10_NO	68	TS9_NO	53	DI11_P	38	DI10_P	23	W2_IN+	8	W2_IN-
84	TS7_12COM	69	TS11_NO	54	DI9_12_ COM	39	DI12_P	24	W3_IA+	9	W3_IA-
85	TS13_NO	70	TS12_NO	55	DI14_P	40	DI13_P	25	W3_IB+	10	W3_IB-
86	TS13_16COM	71	TS14_NO	56	DI16_P	41	DI15_P	26	W3_IC+	11	W3_IC-
87	TS15_NC	72	TS15_NO	57	DI13_16COM	42	RS485_1D+	27	W3_IN+	12	W3_IN-
88	TS16_NC	73	TS16_NO	58	RS485_2D+	43	RS485_1D-	28	VA+	13	VA-
89	PWR+	74	CHASSIC	59	RS485_2D-	44	RS485_1COM	29	-	14	-
90	PWR-	75	SURGE	60	RS485_2COM	45	SURGE	30	-	15	SURGE

5.3 External Connections

5.3.1 PAC-T100 three windings transformer CT connection

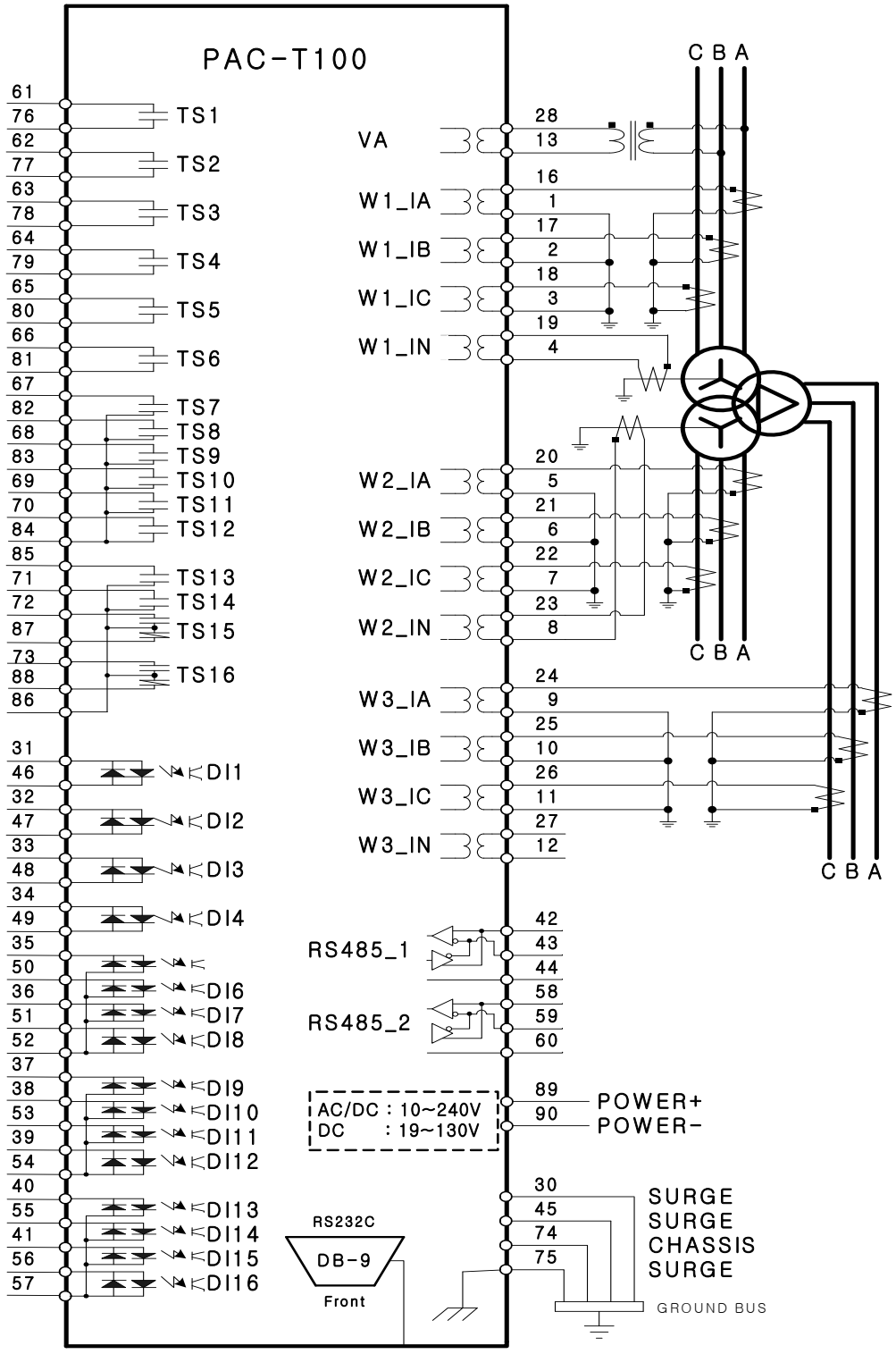


Figure 5-2 PAC-T100 three windings transformer CT connection

5.3.2 PAC-T100 two windings transformer CT connection (PHS COMP : INTERNAL)

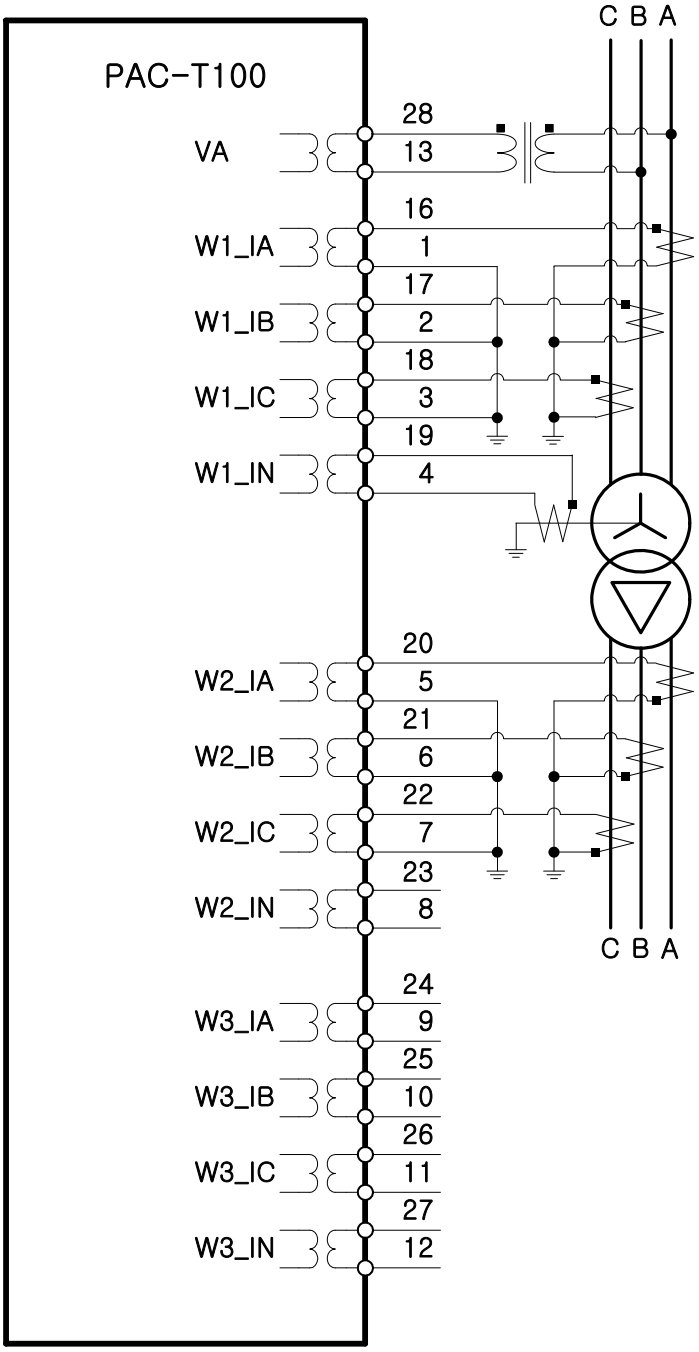


Figure 5-3 PAC-T100 two windings transformer CT connection

5.3.3 Current Transformer(CT) Connection for External Phase Compensation (PHS COMP : EXTERNAL)

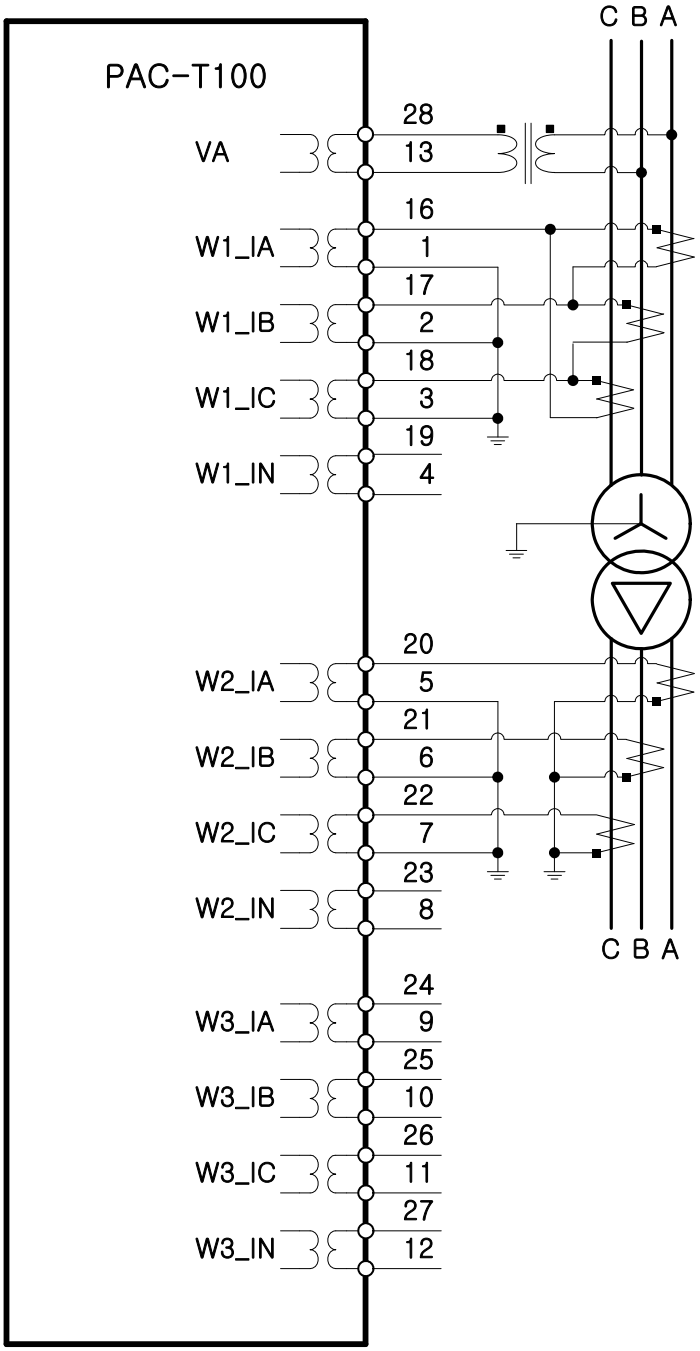


Figure 5-4 Current Transformer(CT) Connection for External Phase Compensation

5.3.4 Input/Output contact connection

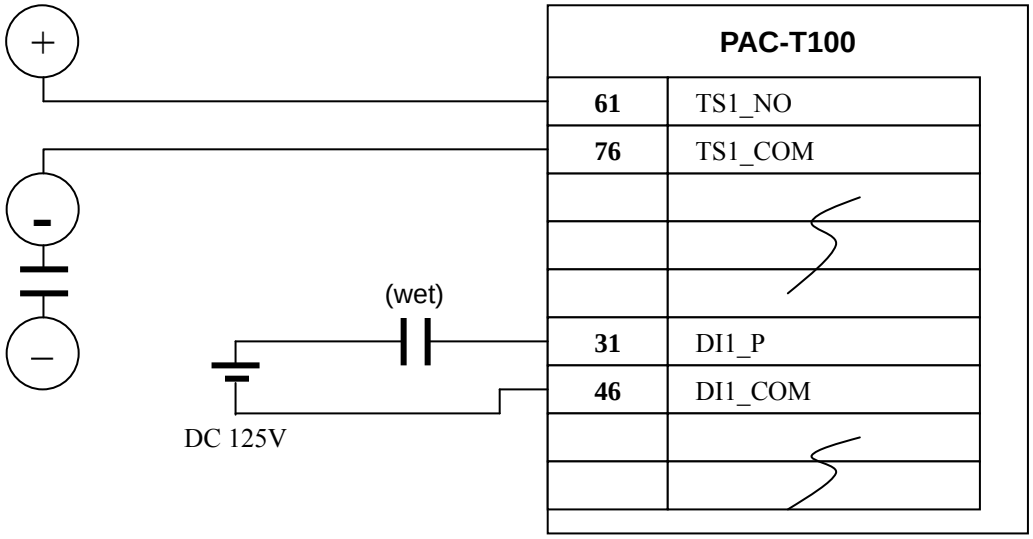


Figure 5-5 Input/Output contact connection

5.3.5 RS232 Port Connection

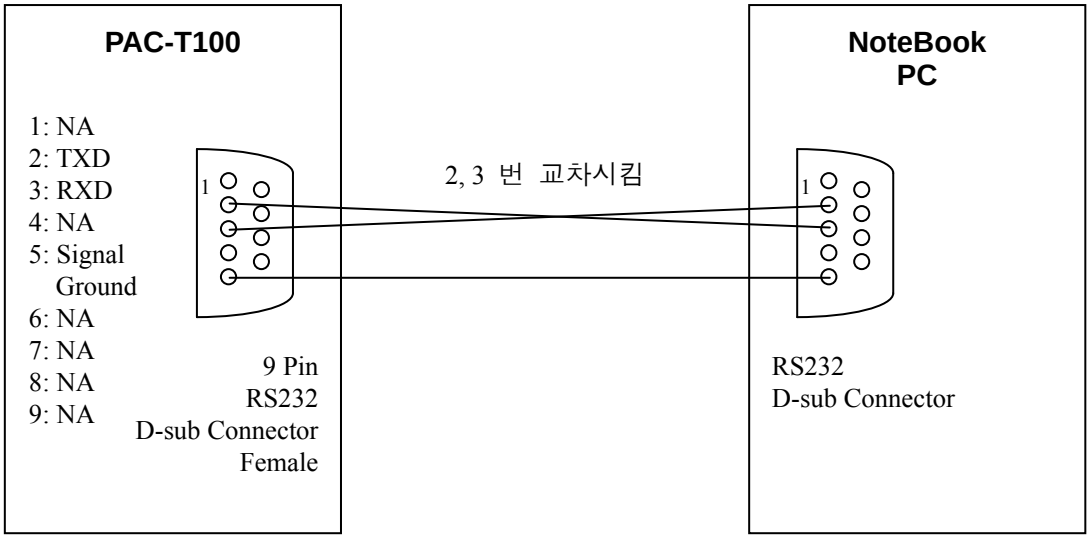


Figure 5-6 RS232 Port Connection

5.3.6 RS485 Port Connection

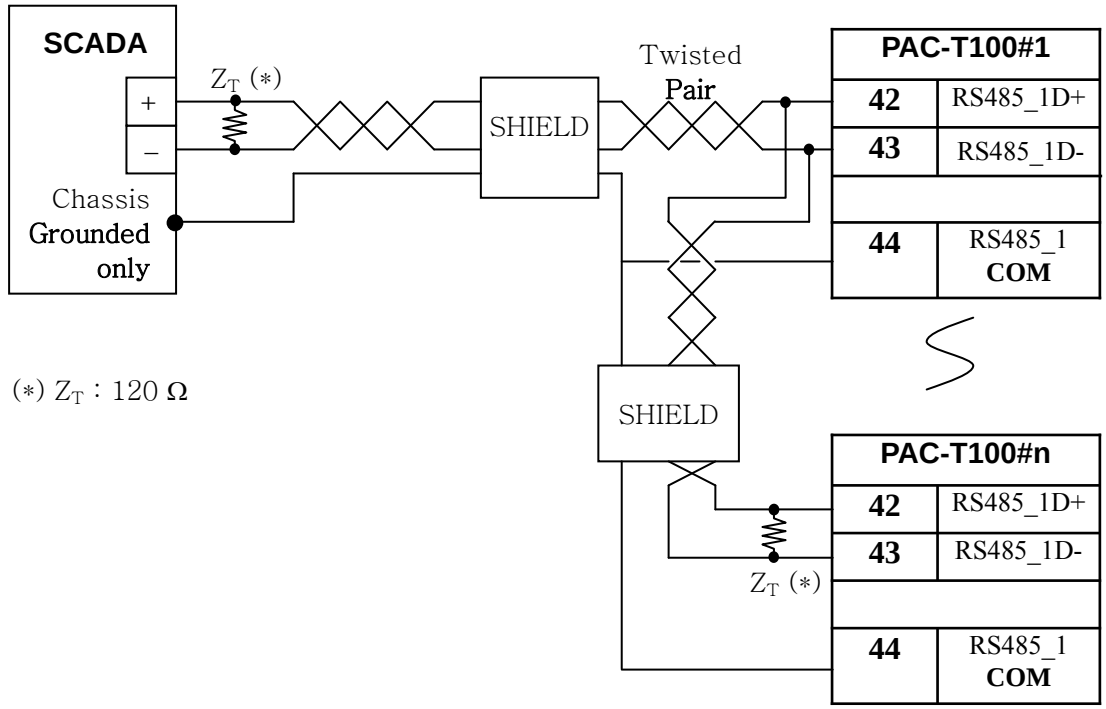
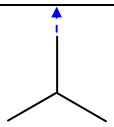
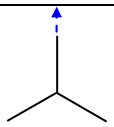
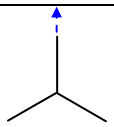
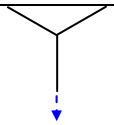
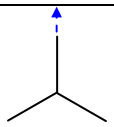
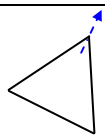
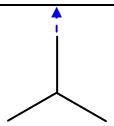
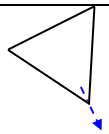
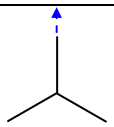
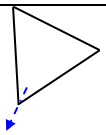
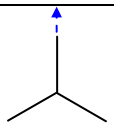
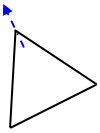
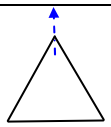
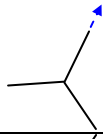
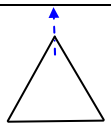
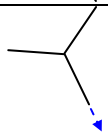
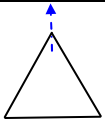
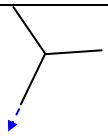
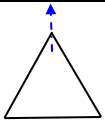
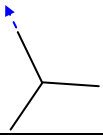


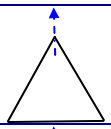
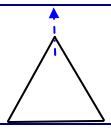
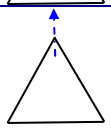
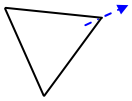
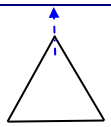
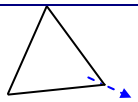
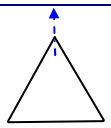
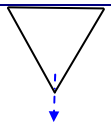
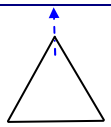
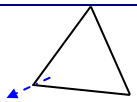
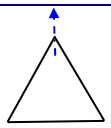
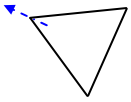
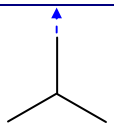
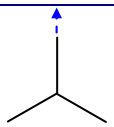
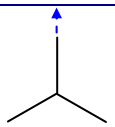
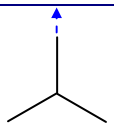
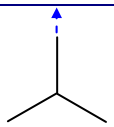
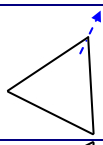
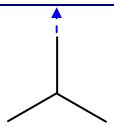
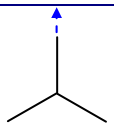
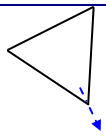
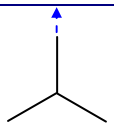
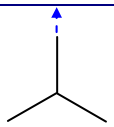
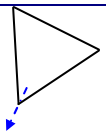
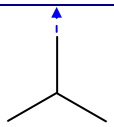
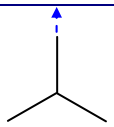
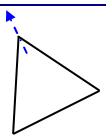
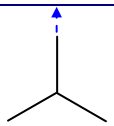
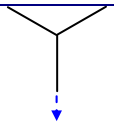
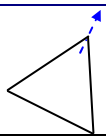
Figure 5-7 RS485 port connection

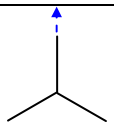
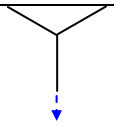
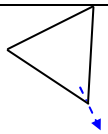
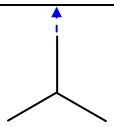
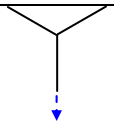
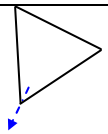
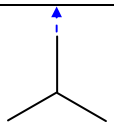
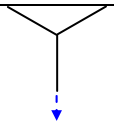
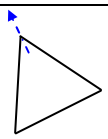
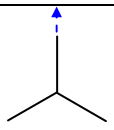
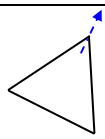
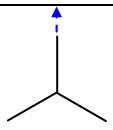
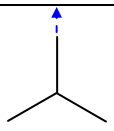
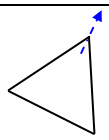
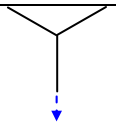
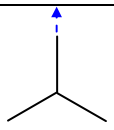
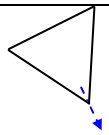
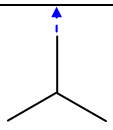
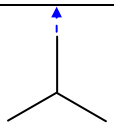
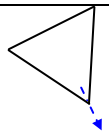
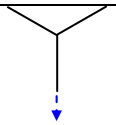
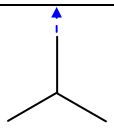
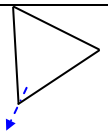
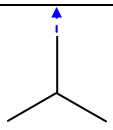
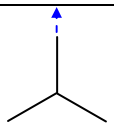
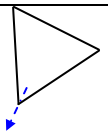
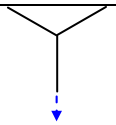
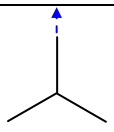
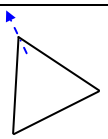
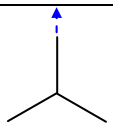
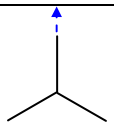
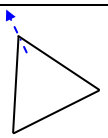
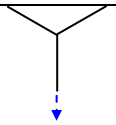
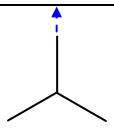
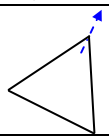
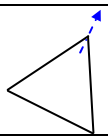
Appendix A. Phase compensation formula

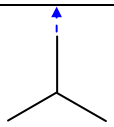
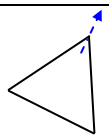
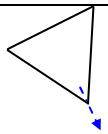
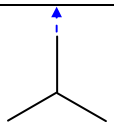
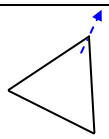
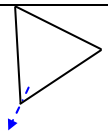
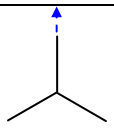
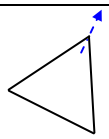
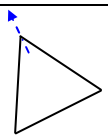
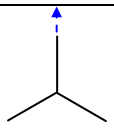
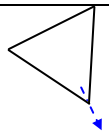
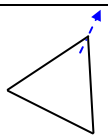
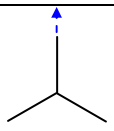
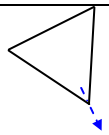
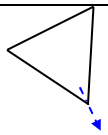
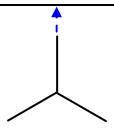
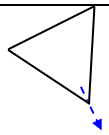
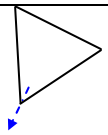
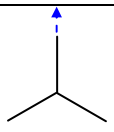
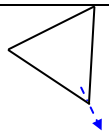
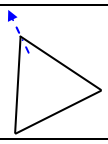
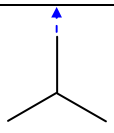
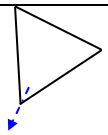
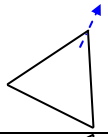
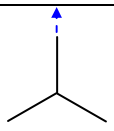
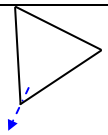
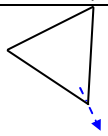
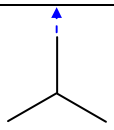
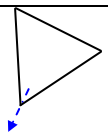
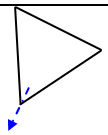
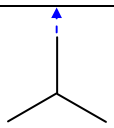
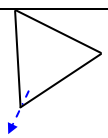
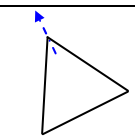
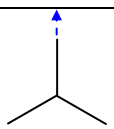
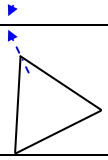
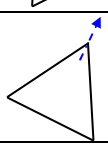
Compensation angle(°lag)	Phase compensation	
	GROUND : NO	GROUND : YES
0	$I_A^* = I_A$ $I_B^* = I_B$ $I_C^* = I_C$	$I_A^* = 2/3\ I_A - 1/3\ I_B - 1/3\ I_C$ $I_B^* = 2/3\ I_B - 1/3\ I_C - 1/3\ I_A$ $I_C^* = 2/3\ I_C - 1/3\ I_A - 1/3\ I_B$
30	$I_A^* = 1/\sqrt{3}\ I_A - 1/\sqrt{3}\ I_C$ $I_B^* = 1/\sqrt{3}\ I_B - 1/\sqrt{3}\ I_A$ $I_C^* = 1/\sqrt{3}\ I_C - 1/\sqrt{3}\ I_B$	
60	$I_A^* = -I_C$ $I_B^* = -I_A$ $I_C^* = -I_B$	$I_A^* = -2/3\ I_C + 1/3\ I_A + 1/3\ I_B$ $I_B^* = -2/3\ I_A + 1/3\ I_B + 1/3\ I_C$ $I_C^* = -2/3\ I_B + 1/3\ I_C + 1/3\ I_A$
90	$I_A^* = 1/\sqrt{3}\ I_B - 1/\sqrt{3}\ I_C$ $I_B^* = 1/\sqrt{3}\ I_C - 1/\sqrt{3}\ I_A$ $I_C^* = 1/\sqrt{3}\ I_A - 1/\sqrt{3}\ I_B$	
120	$I_A^* = I_B$ $I_B^* = I_C$ $I_C^* = I_A$	$I_A^* = 2/3\ I_B - 1/3\ I_C - 1/3\ I_A$ $I_B^* = 2/3\ I_C - 1/3\ I_A - 1/3\ I_B$ $I_C^* = 2/3\ I_A - 1/3\ I_B - 1/3\ I_C$
150	$I_A^* = 1/\sqrt{3}\ I_B - 1/\sqrt{3}\ I_A$ $I_B^* = 1/\sqrt{3}\ I_C - 1/\sqrt{3}\ I_B$ $I_C^* = 1/\sqrt{3}\ I_A - 1/\sqrt{3}\ I_C$	
180	$I_A^* = -I_A$ $I_B^* = -I_B$ $I_C^* = -I_C$	$I_A^* = -2/3\ I_A + 1/3\ I_B + 1/3\ I_C$ $I_B^* = -2/3\ I_B + 1/3\ I_C + 1/3\ I_A$ $I_C^* = -2/3\ I_C + 1/3\ I_A + 1/3\ I_B$
210	$I_A^* = 1/\sqrt{3}\ I_C - 1/\sqrt{3}\ I_A$ $I_B^* = 1/\sqrt{3}\ I_A - 1/\sqrt{3}\ I_B$ $I_C^* = 1/\sqrt{3}\ I_B - 1/\sqrt{3}\ I_C$	
240	$I_A^* = I_C$ $I_B^* = I_A$ $I_C^* = I_B$	$I_A^* = 2/3\ I_C - 1/3\ I_A - 1/3\ I_B$ $I_B^* = 2/3\ I_A - 1/3\ I_B - 1/3\ I_C$ $I_C^* = 2/3\ I_B - 1/3\ I_C - 1/3\ I_A$
270	$I_A^* = 1/\sqrt{3}\ I_C - 1/\sqrt{3}\ I_B$ $I_B^* = 1/\sqrt{3}\ I_A - 1/\sqrt{3}\ I_C$ $I_C^* = 1/\sqrt{3}\ I_B - 1/\sqrt{3}\ I_A$	
300	$I_A^* = -I_B$ $I_B^* = -I_C$ $I_C^* = -I_A$	$I_A^* = -2/3\ I_B + 1/3\ I_C + 1/3\ I_A$ $I_B^* = -2/3\ I_C + 1/3\ I_A + 1/3\ I_B$ $I_C^* = -2/3\ I_A + 1/3\ I_B + 1/3\ I_C$
330	$I_A^* = 1/\sqrt{3}\ I_A - 1/\sqrt{3}\ I_B$ $I_B^* = 1/\sqrt{3}\ I_B - 1/\sqrt{3}\ I_C$ $I_C^* = 1/\sqrt{3}\ I_C - 1/\sqrt{3}\ I_A$	

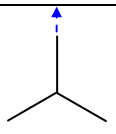
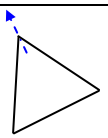
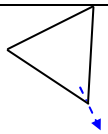
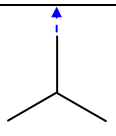
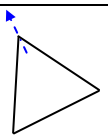
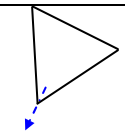
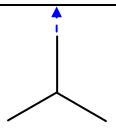
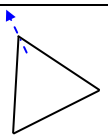
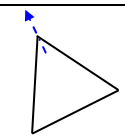
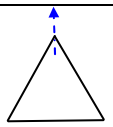
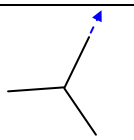
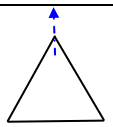
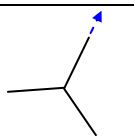
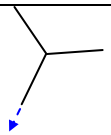
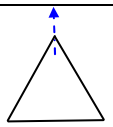
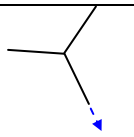
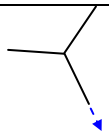
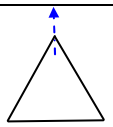
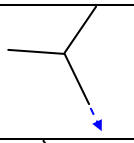
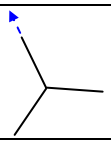
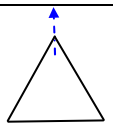
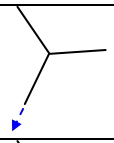
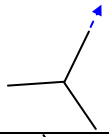
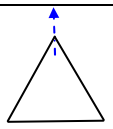
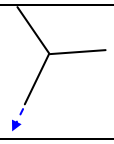
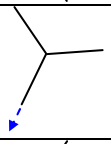
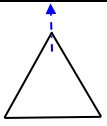
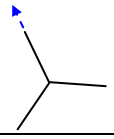
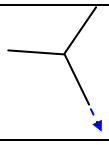
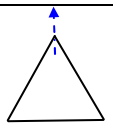
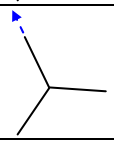
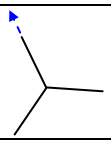
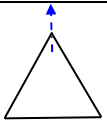
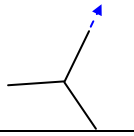
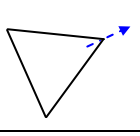
Appendix B. Transformer type and compensation angle

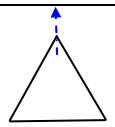
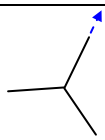
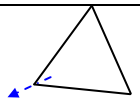
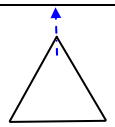
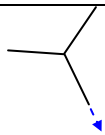
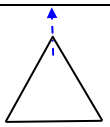
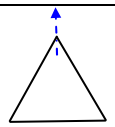
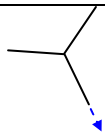
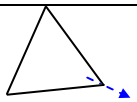
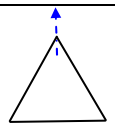
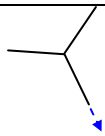
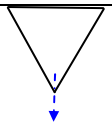
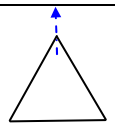
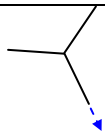
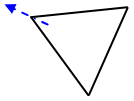
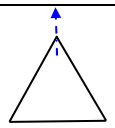
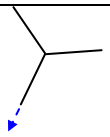
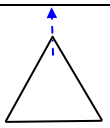
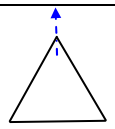
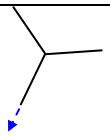
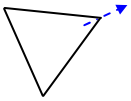
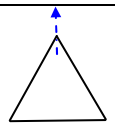
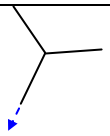
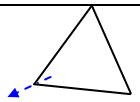
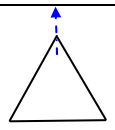
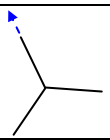
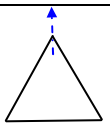
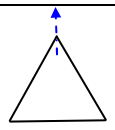
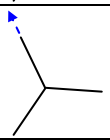
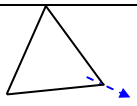
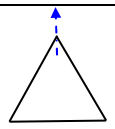
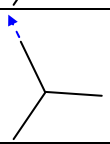
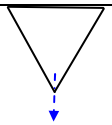
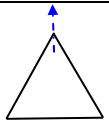
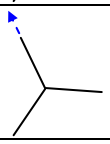
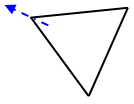
Transformer setting			Vector diagram			Compensation angle(lag)		
TYPE	**W1-W2 PHS**	**W1-W3 PHS**	**W1**	**W2**	**W2**	**W1**	**W2**	**W3**
Y_Y	0	*				0	0	0
	180	*				180	0	0
Y_D	30	*				30	0	0
	150	*				150	0	0
	210	*				210	0	0
	330	*				330	0	0
D_Y	30	*				0	330	0
	150	*				0	210	0
	210	*				0	150	0
	330	*				0	30	0

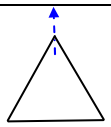
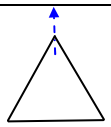
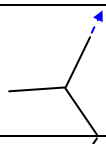
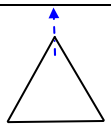
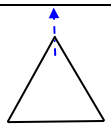
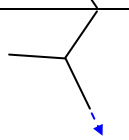
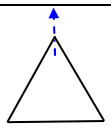
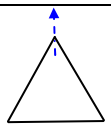
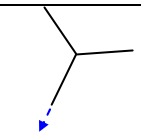
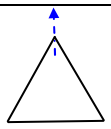
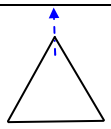
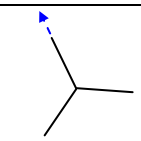
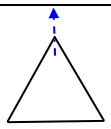
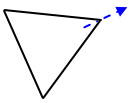
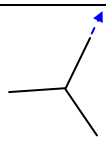
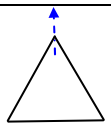
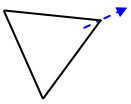
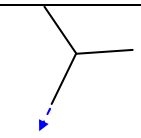
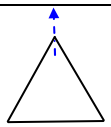
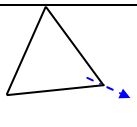
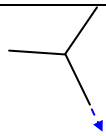
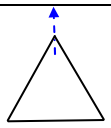
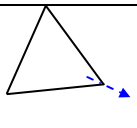
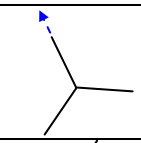
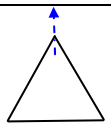
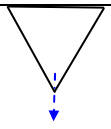
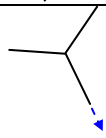
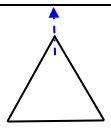
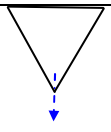
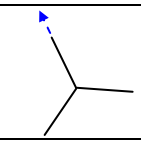
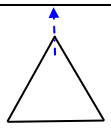
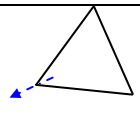
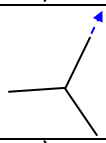
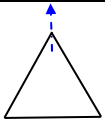
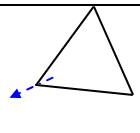
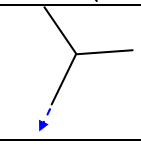
D_D	0	*				0	0	0
	60	*				60	0	0
	120	*				120	0	0
	180	*				180	0	0
	240	*				240	0	0
	300	*				300	0	0
Y_Y_Y	0	0				0	0	0
Y_Y_D	0	30				30	30	0
		150				150	150	0
		210				210	210	0
		330				330	330	0
Y_Y_D	180	30				30	210	0

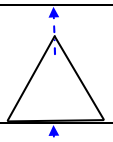
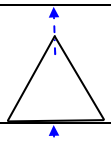
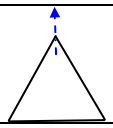
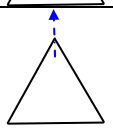
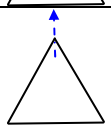
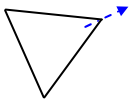
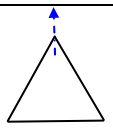
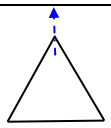
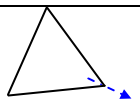
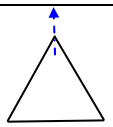
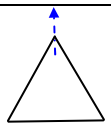
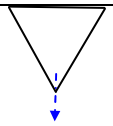
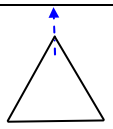
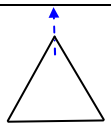
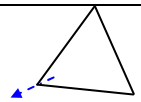
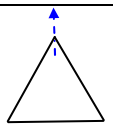
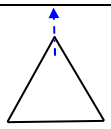
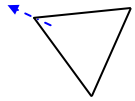
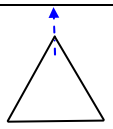
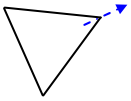
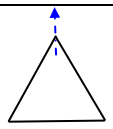
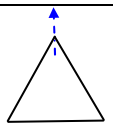
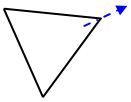
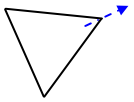
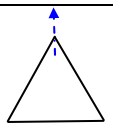
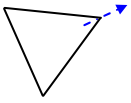
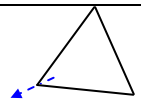
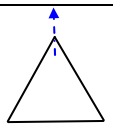
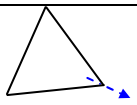
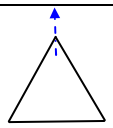
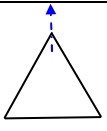
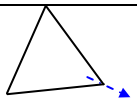
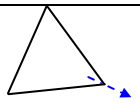
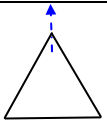
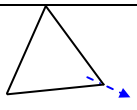
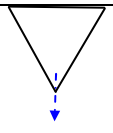
		150				150	330	0
		210				210	30	0
		330				330	150	0
Y_D_Y	30	0				30	0	30
		180				30	0	210
	150	0				150	0	150
		180				150	0	330
	210	0				210	0	210
		180				210	0	30
	330	0				330	0	330
		180				330	0	150
Y_D_D	30	30				30	0	0

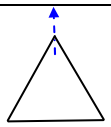
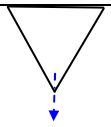
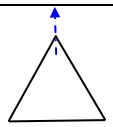
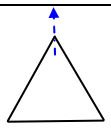
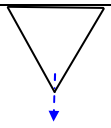
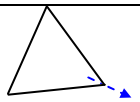
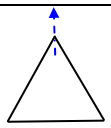
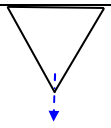
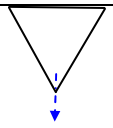
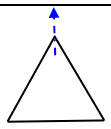
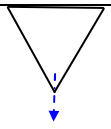
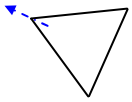
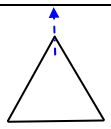
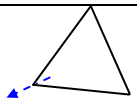
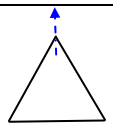
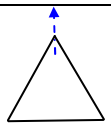
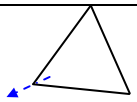
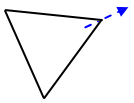
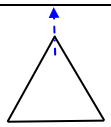
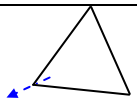
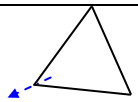
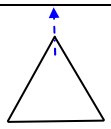
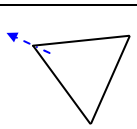
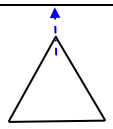
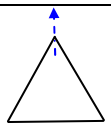
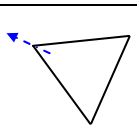
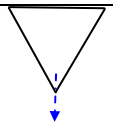
		150				30	0	240
		210				30	0	180
		330				30	0	60
	150	30				150	0	120
		150				150	0	0
		210				150	0	300
		330				150	0	180
	210	30				210	0	180
		150				210	0	60
		210				210	0	0
		330				210	0	240
Y_D_D	330	30				330	0	300

		150				330	0	180
		210				330	0	120
		330				330	0	0
D_Y_Y	30	30				0	330	330
		210				0	330	150
	150	150				0	210	210
		330				0	210	30
	210	30				0	150	330
		210				0	150	150
	330	150				0	30	210
		330				0	30	30
D_Y_D	30	60				0	330	300

		240				0	330	120
	150	0				0	210	0
		120				0	210	240
		180				0	210	180
		300				0	210	60
	210	0				0	150	0
		60				0	150	300
		240				0	150	120
	330	0				0	30	0
		120				0	30	240
		180				0	30	180
		300				0	30	60

D_D_Y	0	30				0	0	300
		150				0	0	210
		210				0	0	150
		330				0	0	30
	60	30				0	300	330
		210				0	300	150
	120	150				0	240	210
		330				0	240	30
	180	150				0	180	210
		330				0	180	30
	240	30				0	120	330
		210				0	120	150

D_D_D	0	0				0	0	0
		60				60	60	0
		120				120	120	0
		180				180	180	0
		240				240	240	0
		300				300	300	0
	60	0				60	0	60
		60				60	0	0
		240				240	180	0
	120	0				120	0	120
		120				120	0	0
		180				120	0	300

D_D_D	180	0				180	0	180
		120				120	300	0
		180				0	180	180
		300				300	120	0
	240	0				240	0	240
		60				240	0	180
		240				240	0	0
	300	0				300	0	300
		180				300	0	120
기타	*	*				0	0	0

Appendix C. Time characteristics Curves

- Overcurrent/overvoltage

$$t = \left(\frac{K}{\left(\frac{G}{G_S} \right)^L - 1} + C \right) \times TM(\sec)$$

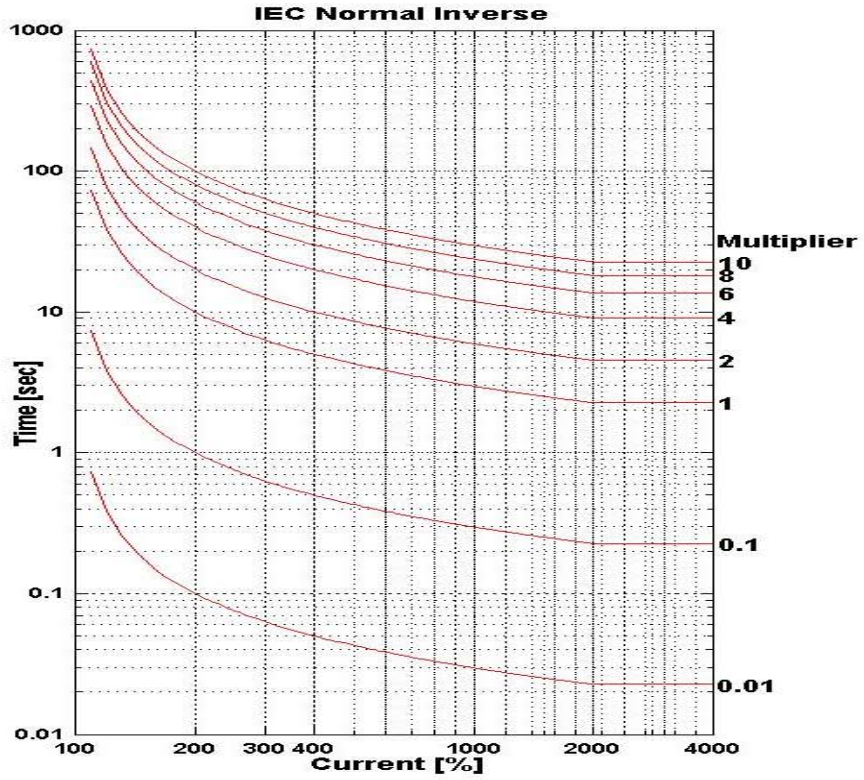
- Undervoltage

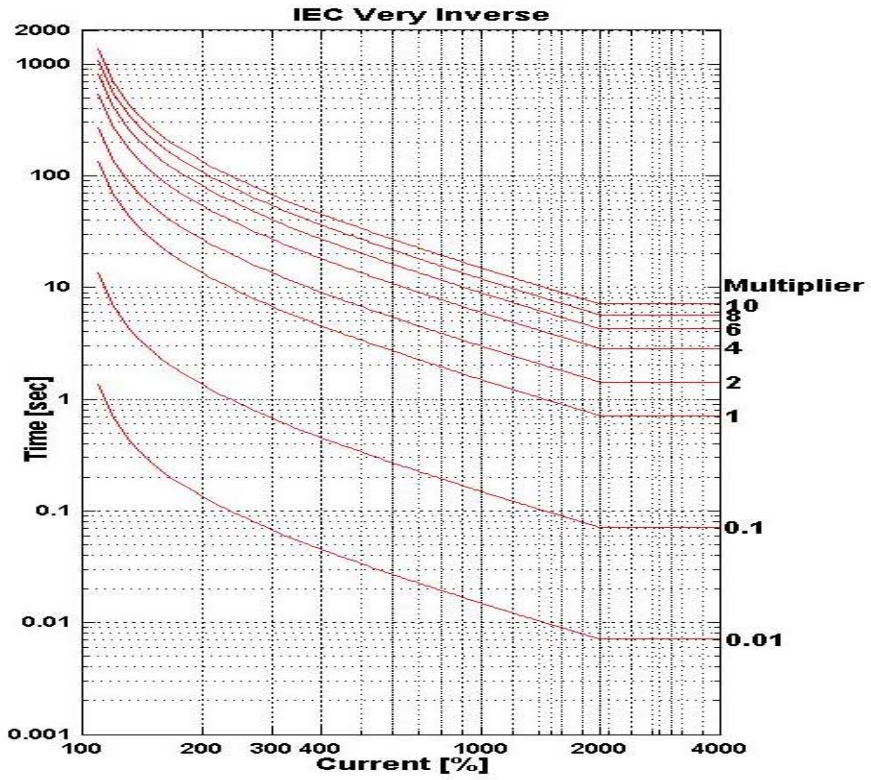
$$t = \left(\frac{K}{1 - \left(\frac{G}{G_S} \right)^L} \right) \times TM(\sec)$$

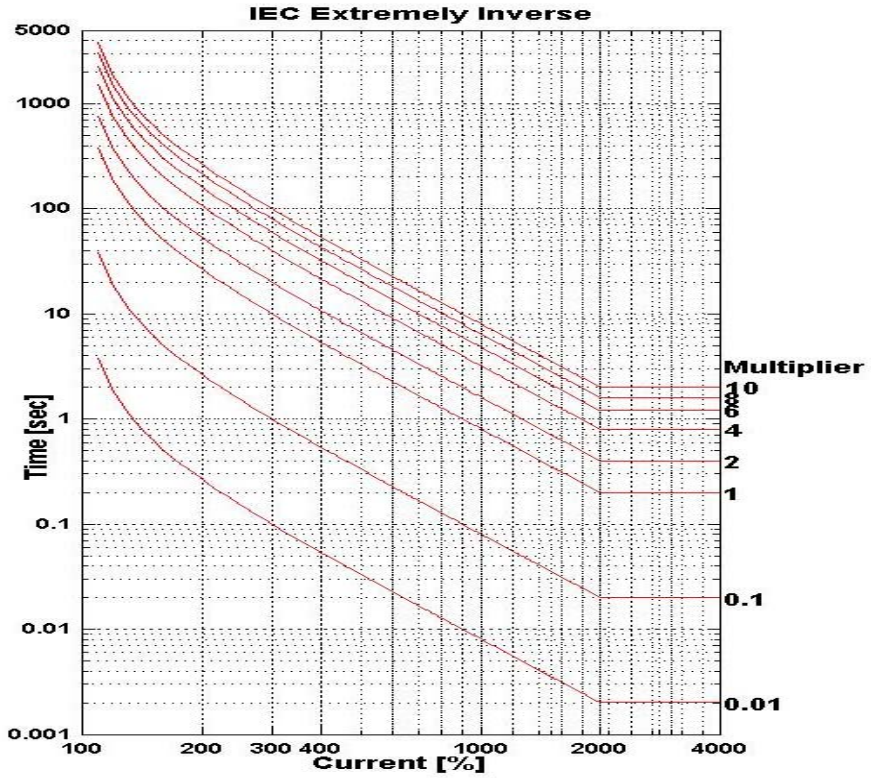
t : Operating time
K, C, L : Characteristic curve const
G : Current(voltage) input
Gs : Current(voltage) setting
TM : Multiplier(0.01~10.00)

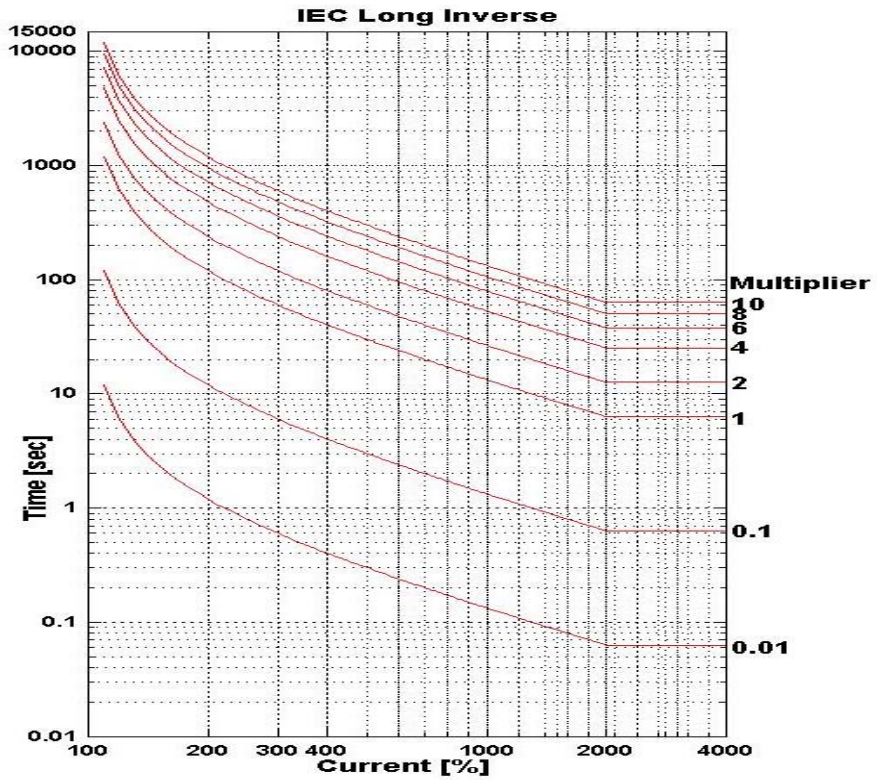
Protection element	TC curve	K	L	C
Phase/Ground Overcurrent(51/51N) Negative Sequence Overcurrent(46T)	IEC Normal Inverse	0.14	0.02	0.00
	IEC Very Inverse	13.50	1.00	0.00
	IEC Extremely Inverse	80.00	2.00	0.00
	IEC Long Inverse	120.00	1.00	0.00
	ANSI Inverse	8.9341	2.0938	0.17966
	ANSI Short Inverse	0.2663	1.2969	0.03393
	ANSI Long Inverse	5.6143	1	2.18592
	ANSI Moderately Inverse	0.0103	0.02	0.0228
	ANSI Very Inverse	3.922	2	0.0982
	ANSI Extremely Inverse	5.64	2	0.02434
	ANSI Definite Inverse	0.4797	1.5625	0.21359
	KEPCO Normal Inverse	0.11	0.02	0.42
	KEPCO Very Inverse	39.85	1.95	1.08
	KEPCO Definite Normal Inverse	0.0515	0.02	0.114
Overvoltage(59)	Inverse	10.5	1.75	0.00
Undervoltage(27)	Inverse	8.0	2.2	0.00

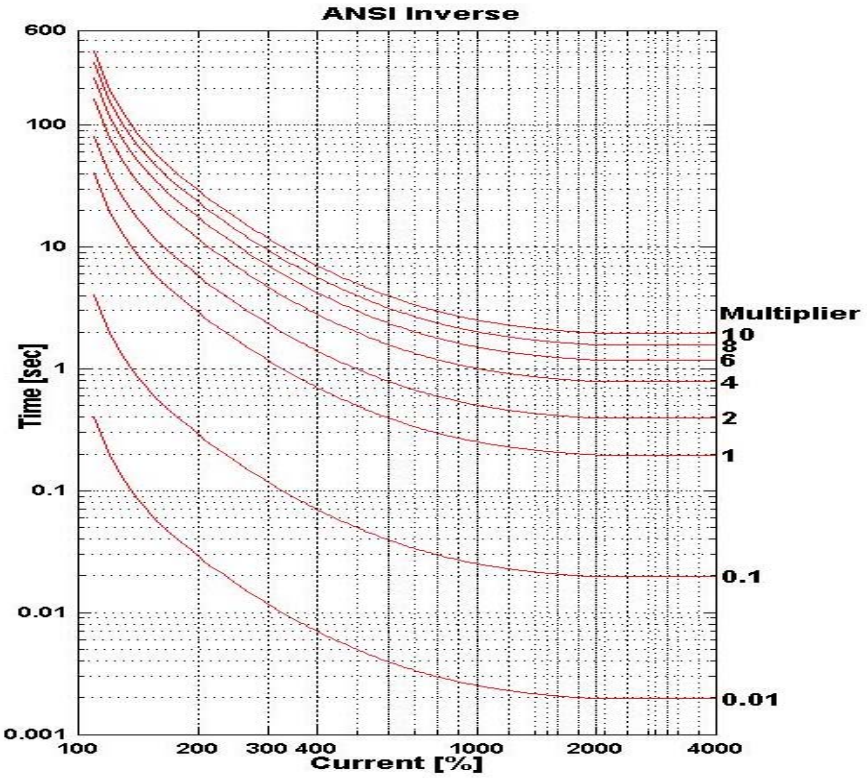
In the case of overcurrent protection element, operating time of current is equal with operating time of 2000% more than 2000% of setting current. In the case of overvoltage protection element, operating time of voltage is equal with operating time of 800% more than 800% of setting voltage.

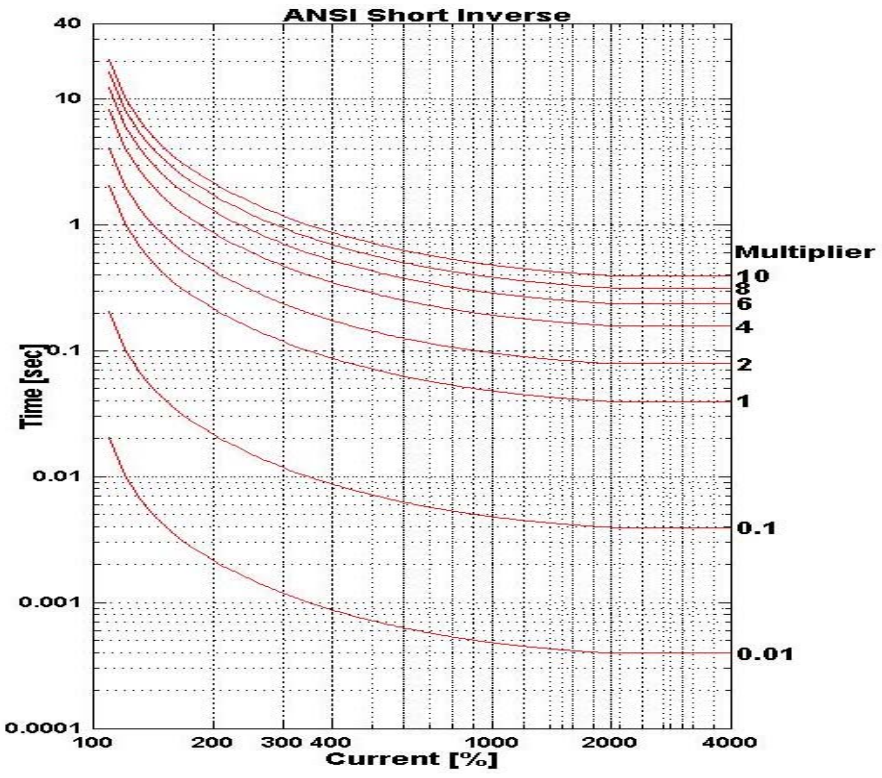

IEC Normal Inverse
1000
100
10
1
0.1
0.01
Time [sec]
100
200
300 400
1000
2000
4000
Current [%]
Multiplier
10
8
6
4
2
1
0.1
0.01

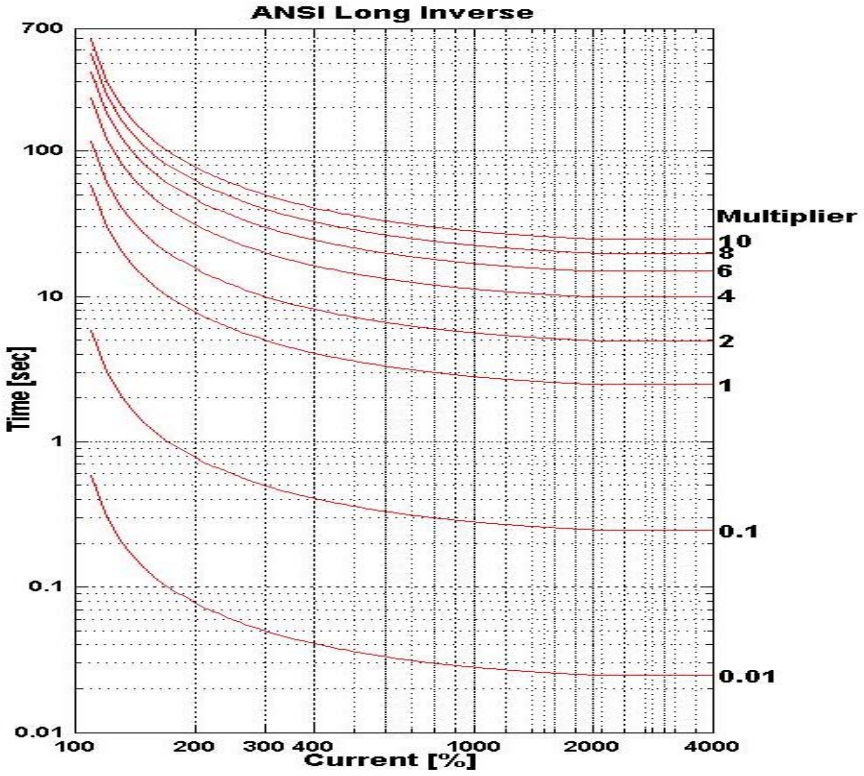

IEC Very Inverse
2000
1000
100
10
1
0.1
0.01
0.001
Time [sec]
100
200
300 400
1000
2000
4000
Current [%]
Multiplier
10
8
6
4
2
1
0.1
0.01

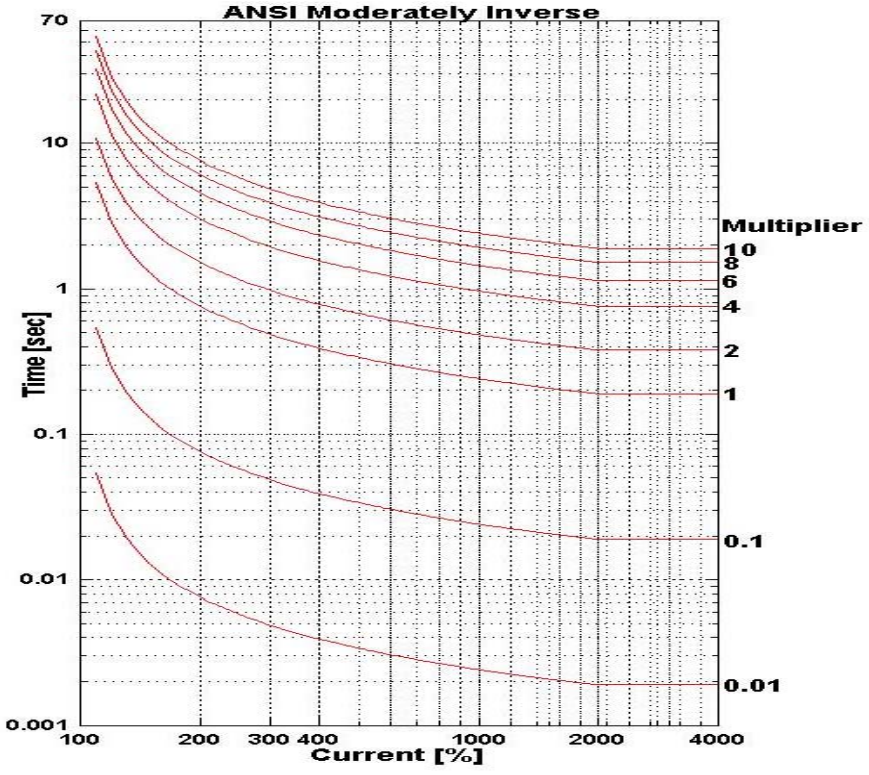

IEC Extremely Inverse
5000
1000
100
10
1
0.1
0.01
0.001
Time [sec]
100
200
300 400
1000
2000
4000
Current [%]
Multiplier
10
8
6
4
2
1
0.1
0.01

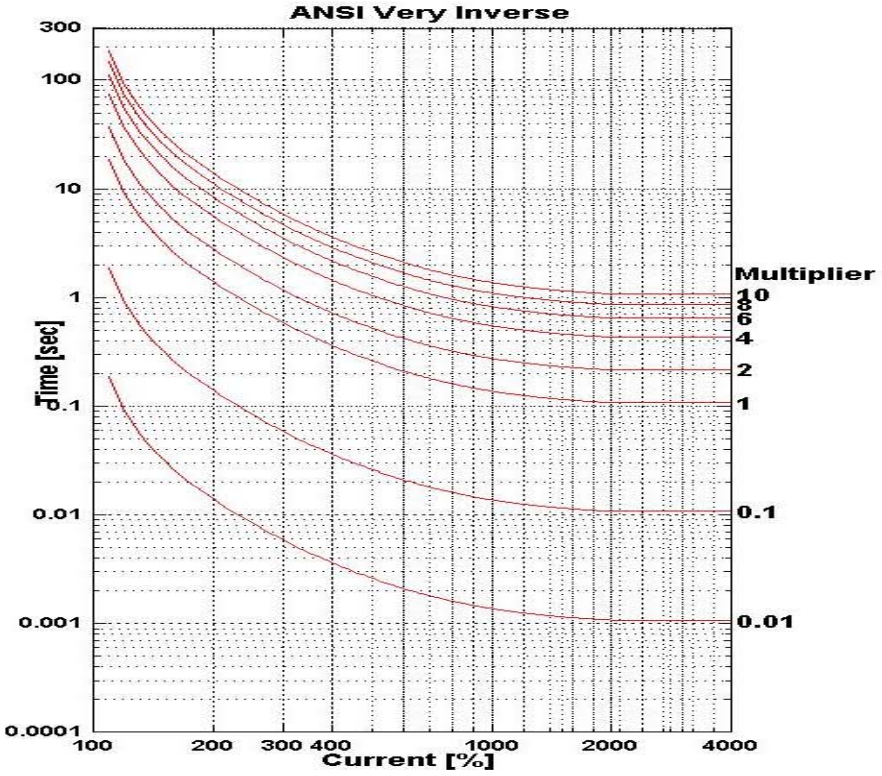

IEC Long Inverse
15000
10000
1000
100
10
1
0.1
0.01
Time [sec]
100
200
300 400
1000
2000
4000
Current [%]
Multiplier
10
8
6
4
2
1
0.1
0.01

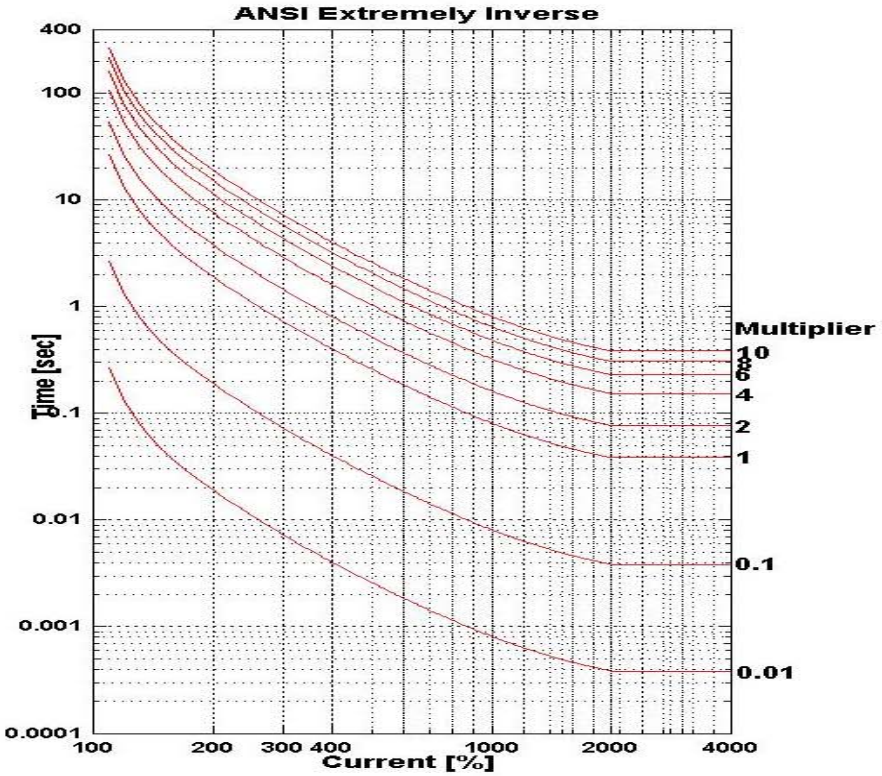

ANSI Inverse
600
100
10
1
0.1
0.01
0.001
Time [sec]
100
200
300 400
1000
2000
4000
Current [%]
Multiplier
10
8
6
4
2
1
0.1
0.01

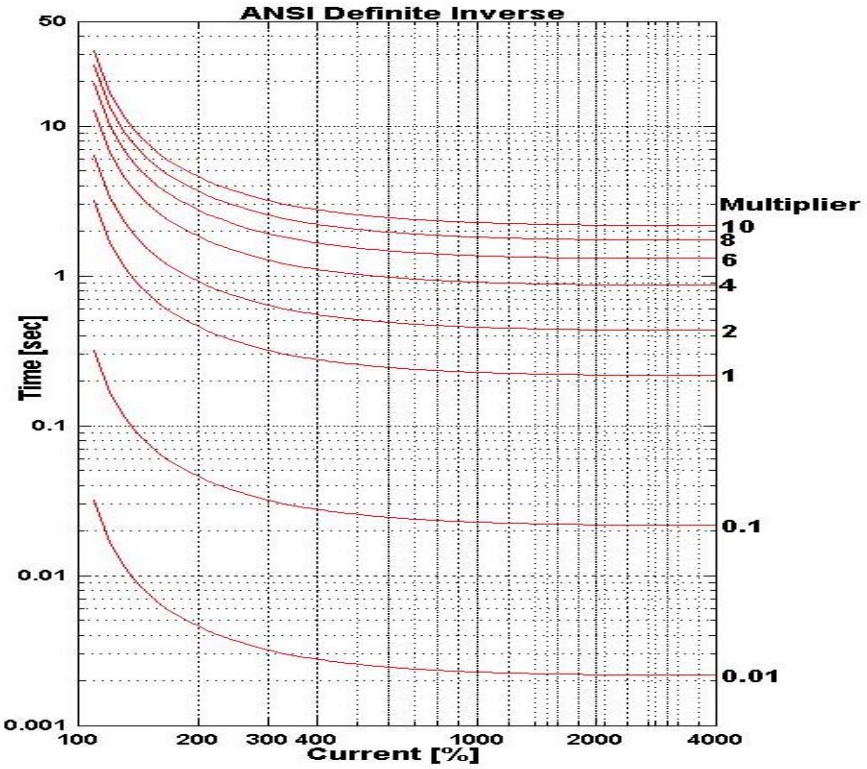

ANSI Short Inverse
40
10
1
0.1
0.01
0.001
0.0001
Time [sec]
100
200
300 400
1000
2000
4000
Current [%]
Multiplier
10
8
6
4
2
1
0.1
0.01

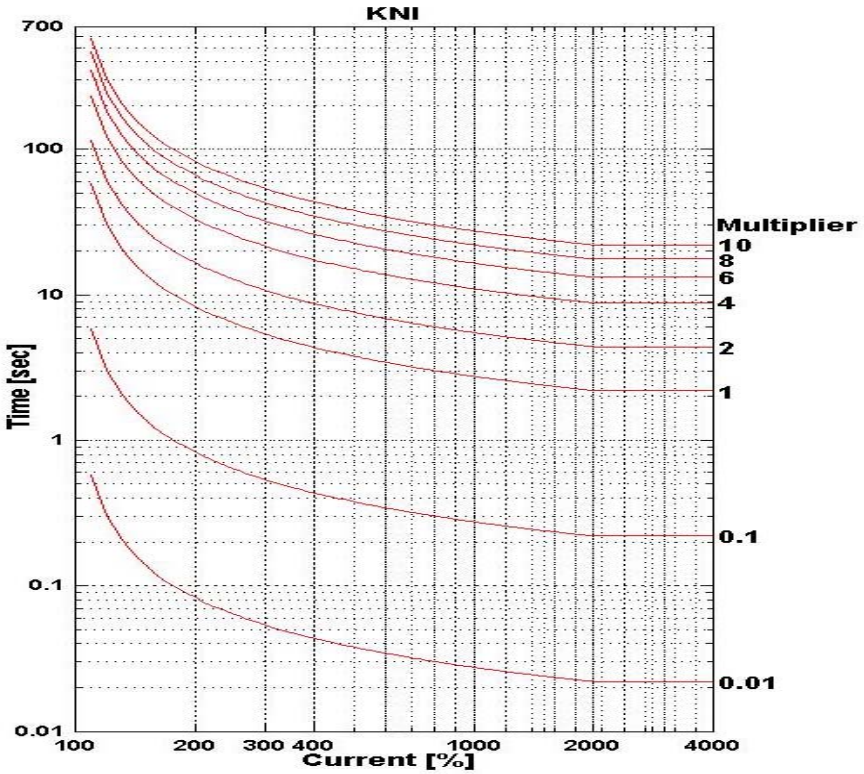

ANSI Long Inverse
700
100
10
1
0.1
0.01
Time [sec]
100
200
300 400
1000
2000
4000
Current [%]
Multiplier
10
8
6
4
2
1
0.1
0.01

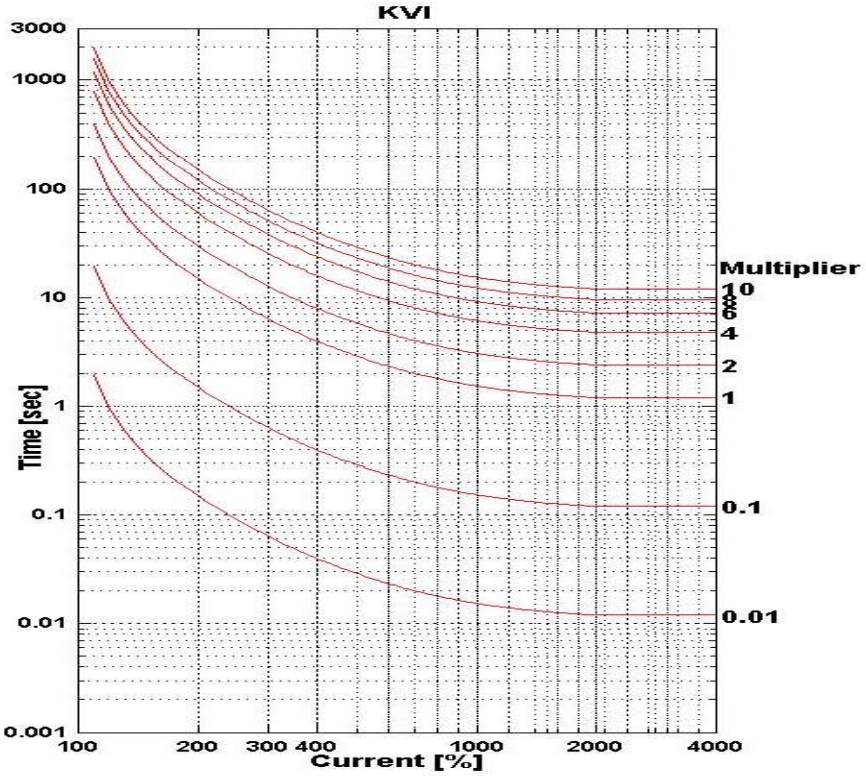

ANSI Moderately Inverse
70
10
1
0.1
0.01
0.001
Time [sec]
100
200
300 400
1000
2000
4000
Current [%]
Multiplier
10
8
6
4
2
1
0.1
0.01

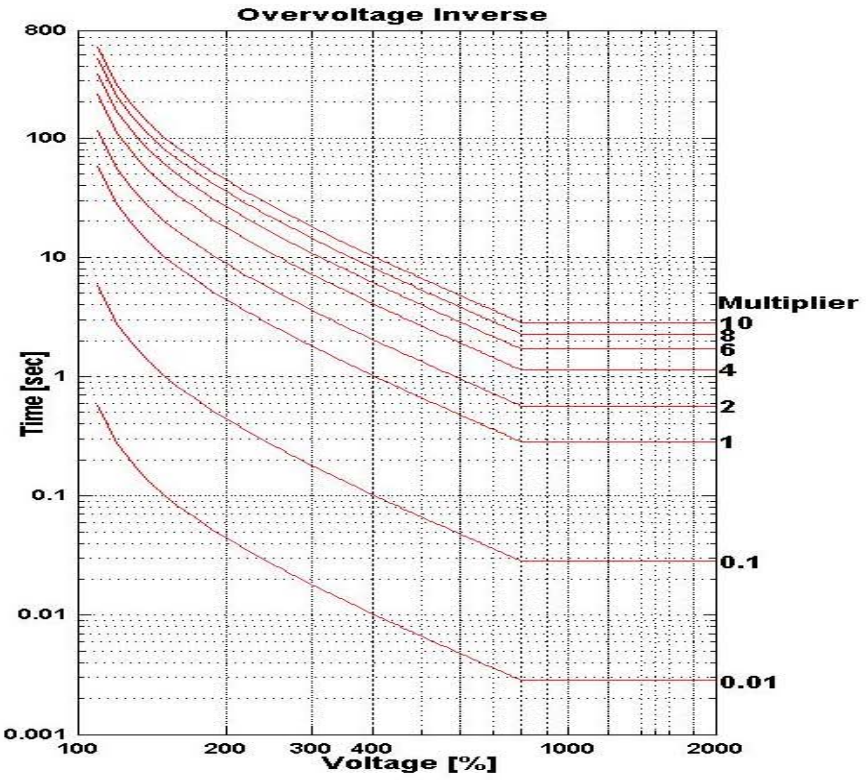

ANSI Very Inverse
300
100
10
1
0.1
0.01
0.001
0.0001
Time [sec]
100
200
300 400
1000
2000
4000
Current [%]
Multiplier
10
8
6
4
2
1
0.1
0.01

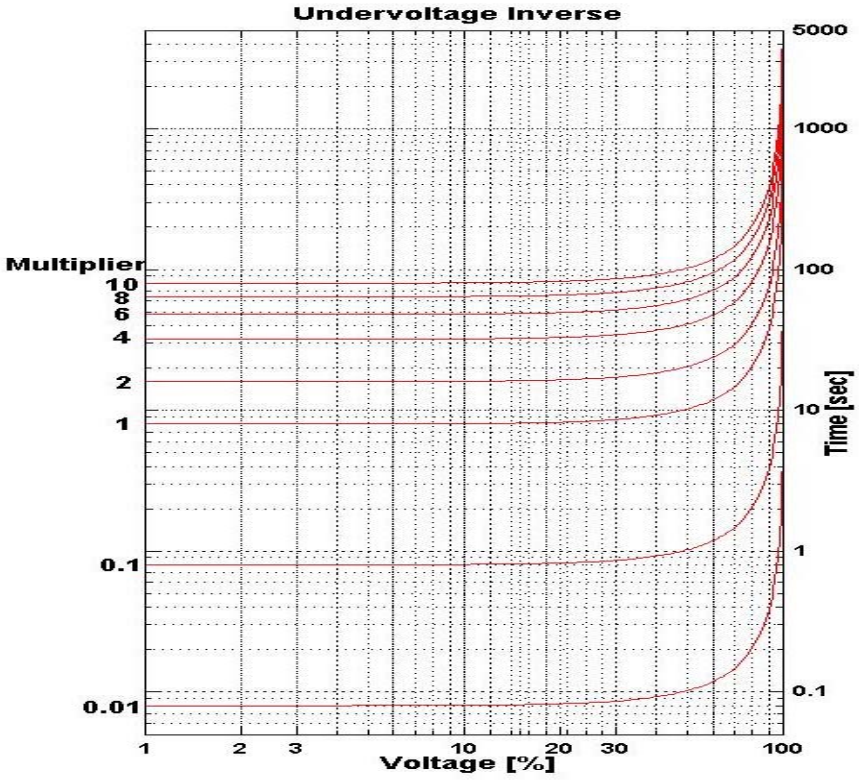

ANSI Extremely Inverse
400
100
10
1
0.1
0.01
0.001
0.0001
Time [sec]
100
200
300 400
1000
2000
4000
Current [%]
Multiplier
10
8
6
4
2
1
0.1
0.01


ANSI Definite Inverse
Time [sec]
50
10
1
0.1
0.01
0.001
100
200
300
400
1000
2000
4000
Current [%]
Multiplier
10
8
6
4
2
1
0.1
0.01


KNI
Time [sec]
700
100
10
1
0.1
0.01
100
200
300
400
1000
2000
4000
Current [%]
Multiplier
10
8
6
4
2
1
0.1
0.01


KVI
3000
1000
100
10
1
0.1
0.01
0.001
Time [sec]
100
200
300 400
1000
2000
4000
Current [%]
Multiplier
10
8
6
4
2
1
0.1
0.01


Overvoltage Inverse
800
100
10
1
0.1
0.01
0.001
Time [sec]
100
200
300 400
1000
2000
Voltage [%]
Multiplier
10
8
6
4
2
1
0.1
0.01


Undervoltage Inverse
Multiplier
10
8
6
4
2
1
0.1
0.01
5000
1000
100
10
1
0.1
Time [sec]
1
2
3
10
20
30
100
Voltage [%]

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